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DIATHERMY

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DIATHERMY

ITS PRODUCTION AND USES IN MEDICINE AND SURGERY

BY

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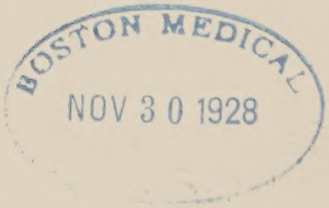

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PREFACE TO THE SECOND EDITION

The progress which has been made in recent years in the medical and surgical uses of diathermy and in the design of apparatus has rendered necessary a complete revision of the preceding edition and a considerable addition to its size. During the preparation of the first edition the field of diathermo-therapy had not been widely explored, and a cautious limitation of the diseases for which the treatment could be confidently prescribed was necessary. At the present time, however, the gain of further knowledge and experience has confirmed the value of diathermy in the diseases for which it was recommended and established its usefulness in the treatment of other maladies. This is particularly the case in many of the diseases peculiar to women and in others due to infection by the gonococcus. The treatment of arthritis by the application of diathermy to the infected cervix uteri or to the ovaries has procured results which are far superior to those obtained by restricting the treatment to the joints. The treatment of the above-mentioned diseases by diathermy has formed an increasingly large part of the work conducted in the Electrical Department of St. Bartholomew's Hospital during the past six years, and the results of the experience gained there are incorporated in the present edition.

The part dealing with the surgical uses of diathermy has been enlarged and almost entirely re-written, and an introductory account of the new "cutting currents" has been added.

In describing the results which may be expected from the use of diathermy I have been guided mainly by my own experience and that of my colleagues at St. Bartholomew's Hospital. The field of diathermo-therapy has, however,

been widened to an extent which renders it no longer possible to treat the subject adequately without describing the experience of others. The names of the workers whose contributions to the science and art of diathermy have been consulted, and those who have developed the use of the high-frequency oscillatory current for cutting, are recorded in the index of authors and in the relevant portions of the text.

E. P. CUMBERBATCH.

Upper Wimpole Street,
August, 1927.

PREFACE

The present book has been written in the hope that it may provide a guide to those who wish to learn the principles and practice of a method of treatment which has conclusively proved its value in medicine and surgery during the ten years in which it has been used in this country. In describing the action of diathermy on excised tissue and the living subject, its method of application and its therapeutic properties, I have been guided mainly by my own experience and investigation.

In the part dealing with the uses of diathermy in surgery, I have described cases which have been under the care of colleagues at St. Bartholomew's Hospital. In these I have either controlled the apparatus or undertaken the treatment at their request, and I am much indebted to them for permission to publish the results. Acknowledgment is made in the respective cases.

The present occasion is opportune for paying a tribute to the memory of the late Dr. Lewis Jones, who introduced diathermy into this country. To his untiring labour, the development of electrotherapeutics in England, and its advance along scientific lines, are mainly due. I may also be allowed to mention the name of the surgeon in charge of the Department of Laryngology at St. Bartholomew's Hospital, Mr. Douglas Harmer, who was the first in this country to recognise the value of diathermy in surgery and adopt it for treatment. His work has aided, in no small degree, the advance of surgical diathermy in this country.

The nucleus of the present work was commenced in 1914,

in the form of a series of articles contributed to the *Archives of the Roentgen Ray* (" Archives of Radiology and Electrotherapy "). The late war and the fulfilment of additional duties hindered their completion, while the acquisition of new knowledge and further experience delayed the publication of the complete work to the present date.

E. P. CUMBERBATCH.

Upper Wimpole Street.
January, 1921.

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CHAPTER I

INTRODUCTION

The term diathermy, which means *through-heating*, was introduced to describe the physical effect of passing an electric current of special kind through the body. This current generates heat along its path, so that, when it traverses the body, not only the skin but the underlying parts are heated. The tissues are therefore heated *throughout*, not merely on the surface; that is to say, "diathermy" is produced.

The customary methods of applying heat to the body for therapeutic purposes do not procure diathermy. In these methods the heat is derived from some external source. An object which is heated to a higher temperature than that of the body is placed either in direct contact with the latter or at a distance from it. In the first case the heat is conveyed to the body by *conduction*, in the second by *radiation*. By neither of these processes is it possible to raise the temperature of the tissues which lie more than a slight depth below the surface.

If a fomentation or hot-water bag is placed on the skin the passage of heat below the surface is slow because the tissues are poor conductors. Even if the heat is applied for a long period it cannot penetrate for more than a slight depth. After passing through the epithelium it reaches the underlying capillaries. Further penetration is impeded, if not entirely prevented, by the blood which conveys the heat away from the parts through which it circulates. The temperature attains its maximum on the surface, falls rapidly below the epithelium and probably sinks to normal in or immediately under the parts occupied by the sub-epithelial capillaries.

When the heat is derived from an incandescent lamp or electric arc or from an object heated insufficiently to produce light it is conveyed to the body by *radiation*. Heat waves,

however, do not penetrate more than a slight depth below the surface of the body. They produce the maximum degree of heat in the skin, and the temperature rapidly subsides as the distance below the surface is increased.[1]

It is possible, by the use of the visible rays from an intense source of light, to raise the temperature a little more deeply than is possible by means of heat rays. Visible rays, especially the red, penetrate further than the heat (infra-red) rays before they are completely absorbed, and their energy is transformed into heat. Before they can be utilised to produce the maximum temperature below the surface the heat rays which accompany them must be stopped.[2] Unless this is done the latter will soon raise the temperature of the skin to the maximum it will tolerate. Even if this precaution is taken it is not possible to procure diathermy.

The heat (infra-red) waves, however, penetrate for a very short distance only, probably not further than the skin, so that the latter alone is heated *directly*: further spread must be by conduction and impeded or prevented by the circulating blood.

When, therefore, the heat is derived from an external source the skin is heated, and the underlying tissues for a trifling distance; in other words, "epithermy" is produced. If the entire skin or a large area of it is heated, the temperature of the internal parts of the body may rise, but the heating is *indirect* and due to the circulation through them of blood heated in its passage through the skin.[3] The heat is in this way distributed to the entire body, and it cannot be restricted to any one region desired.

[1] In an experiment by Sonne the surface was exposed to radiant heat and raised to a temperature of 45·6° C. (114° F.). Five millimetres below the surface the temperature had fallen to 41·6° C. (107° F.). This represents a fall of over one degree F. per millimetre below the surface.

[2] By the use of visible rays Sonne was able to produce a temperature of 47·7° C. (117·8° F.) at a distance five millimetres below the surface. Beyond five millimetres the temperature dropped rapidly.

[3] Some patients were exposed to radiant heat and their oral temperatures noted before and after 20 minutes' exposures. In two cases the trunk was exposed, and a rise of 1·6° was noted in one (97·2 to 98·8), and a rise of 0·8° in the other (98 to 98·8). In four cases, in which one lower limb was exposed, the rises noted were 0·4°, 0·8°, 0·8° and 1°.

To procure diathermy an electric current of special kind is passed through the part which is to be heated. It is well known that when a current passes along a conductor, heat is developed, the amount and degree of heat depending on the resistance of the conductor and the intensity of the current.[1] The body is a conductor of electricity, although its resistance is high, and if it is traversed by a current, heat will be developed in it. If the current is of sufficient strength the heat can be perceived by the body and measured by a thermometer. The heat is, by this method, *actually generated in the tissues along the path of the current* and not, as in the other methods, conveyed to the body "ready made" from an external source by conduction or radiation. By the electric current the heat is generated in all the parts traversed by the current so that the tissues are heated directly, simultaneously, and throughout.

The current which is used to procure diathermy is one which alternates at an exceedingly rapid rate. Such currents are commonly known as "high-frequency" currents.

Other currents cannot be used because they stimulate the excitable tissues of the body, and such stimulation would become unbearable long before the currents reached a strength sufficient to generate perceptible heat. The high-frequency current is unable to stimulate the excitable tissues, and therefore can be raised to a much greater strength, the limit of its toleration being passed only when unbearable heat is produced.

High-frequency currents incapable of producing much heat had been used in medicine for some years without knowledge of the way in which they produced their physiological and therapeutic effects. The ultimate recognition that these effects were due to the heat produced by the current, and the subsequent introduction of the diathermy machine, will be briefly described in the next chapter.

[1] The relation between the amount of heat produced and the strength of the current and the resistance of the circuit is expressed in the following law: The number of units of heat developed in a conductor is proportional (1) to its resistance, (2) to the square of the strength of the current, (3) to the time the current lasts (Joule's law). This law is true for the galvanic current. The same principle holds good in the case of other currents.

Other terms have been used by other workers in place of "diathermy," such as "thermo-penetration," "transthermy" and "endothermy." The term "thermo-penetration" suggests that heat passes into the body; in reality, the heat is generated in the tissues. This term, like "transthermy," is hybrid and inelegant. "Endothermy" is as accurate as "diathermy" if it does not convey the impression that the heat is developed only in the interior of the body and not in the superficial parts; and "diathermy" is as accurate as "endothermy" if it does not convey the idea that the heat *penetrates* through. The term "diathermy," which was introduced by Nagelschmidt, is now established and most widely used.

CHAPTER II

HISTORICAL NOTE

High-frequency currents have been subjects of physical research for many years. Their use in medicine was first suggested by Nikola Tesla, who, in a paper in the *Electrical Engineer*, of December, 1891, noted that when the body was traversed by high-tension currents of high frequency, heat was perceived. It was not, however, till 1898 that an investigation of the action of high-frequency currents in the treatment of disease was commenced. This was conducted by d'Arsonval, professor in the Collège de France, Paris. He had studied the physiological properties of these currents for some years before this. In 1890 he showed that when a current, used to stimulate muscle, reversed its direction more than 5,000 times per second, the contraction became feebler in proportion to the increase in frequency of the alternation. When the frequency exceeded 10,000 the contraction ceased.

In February, 1891, in a communication to the Société de Biologie, d'Arsonval showed that a high-frequency current of three amperes could be passed through the body without producing any sensation other than heat.

The power of high-frequency currents to modify the physiological processes of the body was studied by the same worker. He demonstrated their power to increase the respiratory exchange and the nitrogenous bodies and phosphates in the urine. He showed that they could cause dilatation of the peripheral vessels and sometimes lower the arterial blood pressure. He noted also that they could increase the output of heat from the body. In an experiment on himself, in 1895, he found that the output of heat during fifteen minutes increased from 79·4 to 127·4 calories.

How high-frequency currents produced these physiological effects received no satisfactory explanation, and it was thought that the increased production of heat was the result of excessive katabolism.

In 1896 d'Arsonval showed that the passage of a strong high-frequency current along the limbs of a rabbit was followed by their coagulation. In 1900 Bordier and Lecomte performed similar experiments and directed the current

Professor A. d'Arsonval.

The masterly researches of this distinguished pioneer laid the foundation on which diathermo-therapy is based.

through the body by way of electrodes introduced into the mouth and rectum. The rate of respiration gradually increased and finally became so rapid that it could not be counted. The heart-beat became imperceptible and the animal died, the tissue proteins being coagulated.

In 1898 the therapeutic properties of high-frequency cur-

rents were studied by d'Arsonval and demonstrated in certain diseases of the circulatory system. He directed attention to the unpleasant heat ("chaleur désagréable") which was sometimes felt when the body was traversed by strong high-frequency currents. Apparently, however, it was not thought that the physiological and therapeutic effects were due to heat generated by the current.

At the commencement of the present century treatment by "high frequency" began to be popular. Apparatus far less powerful than that used by D'Arsonval was employed and the current yielded an insignificant amount of heat. This was doubtless owing to the belief that the therapeutic properties of the current were due to some action other than that of heat.

In 1899 von Zeyneck, in a paper in the *Göttinger Annale*, on the excitability of the sensory nerve endings to alternating currents, made a brief allusion to the heating-through ("Durchwarmung") of the finger-tips, and interpreted the phenomenon as a consequence of the well-known principle that conductors can be heated by passing an electric current along them. In September, 1907, Nagelschmidt, a Berlin physician, demonstrated, in Dresden, that high-frequency currents caused a *heating-through* of the tissues, and recommended their use for the treatment of diseases of the joints and circulatory system. In February, 1908, von Berndt and von Preiss, in conjunction with von Zeyneck, published a paper on the treatment of joint diseases by high-frequency currents, and spoke of the production of "heat-penetration" as the essential part of the action of these currents.

When the importance of the thermogenetic powers of high-frequency currents was realised, more attention was paid to the design of the machines used for the production of these currents. At the Congress held at Budapest in 1908, Nagelschmidt showed a machine which yielded currents capable of producing a much larger quantity of heat and a higher temperature. The term "diathermy" was introduced in recognition of the fact that these currents generate heat, and that the heat is distributed through the tissues and not localised to the surface.

It will be seen, from the foregoing brief account, that the

effects of the currents which oscillate with high frequency were tried on the living tissues, in health and disease, without knowledge of the way in which the effects were produced or why these currents could not stimulate excitable tissues; that it was recognised some years later that the physiological and therapeutic results were the consequence of the heat which these currents produced, and that the heat was not restricted to the surface, but was developed throughout the tissues. Apparatus capable of yielding high-frequency currents that could generate large quantities of heat was then constructed, and the term " diathermy " was introduced to express the action of the modern medical high-frequency machine. Last of all, in the light of modern research on the excitability of muscle and nerve, a satisfactory explanation was obtained of the inability of high-frequency currents to stimulate these tissues.

Diathermy was introduced into England by Lewis Jones, formerly Medical Officer to the Electrical Department of St. Bartholomew's Hospital, in 1909. A machine by Schall was used in the Electrical Department of that hospital during the same year. The following year, a machine by Siemens was installed, and Nagelschmidt demonstrated its use in the Department on October 21st, 1910, on three surgical cases. This was the first occasion of the use of diathermy in surgery in this country. During recent years the advantages of diathermy, both in surgery and in medicine, have been realised, and diathermo-therapy is now widely practised.

CHAPTER III

HIGH-FREQUENCY CURRENTS

In this chapter are described the physical principles on which high-frequency currents are produced and the factors which determine the frequency and duration of the oscillation.

To generate a perceptible and measurable amount of heat in the tissues, a current very much stronger than those used for other therapeutic purposes is required. It must, therefore, be deprived of its power to stimulate the excitable tissues and to cause chemical (electrolytic) changes. This can be done by making it alternate at an exceedingly high rate. The current is then said to alternate or oscillate with "high frequency." It is known by the abbreviated title "high-frequency current."

The number of times per second a current must reverse (that is, the *height* of its frequency of oscillation), if it is to lose its stimulating and electrolytic powers, depends on its strength. A strong current must alternate with higher frequency than a weak current, but when the frequency exceeds a certain critical height the current loses its stimulating and electrolytic powers, whatever its strength may be. The number of alternations necessary for this purpose cannot be precisely stated, but it may be regarded as not less than 500,000 per second.

Principle on which High-frequency Currents are produced.

No mechanical alternator can reverse a current with such a high frequency as that stated above. High-frequency currents for use in medicine are obtained on quite a different principle. If a condenser, such as a Leyden jar, is charged and then allowed to discharge by connecting its outer and inner coats by a conductor, a current of momentary duration will pass along the conductor. Under certain circumstances this current will flow, not in one direction only, but back-

wards and forwards between the coats, becoming feebler with each reversal, till it ceases. This form of discharge is said to be "oscillatory." It is graphically represented in Fig. 1.

A phenomenon analogous to the oscillatory discharge is seen when a fluid, such as mercury, confined in one limb of a tall U-tube, is suddenly allowed to enter the other limb by releasing an obstruction at the bend. The mercury does not at once reach the same level in each limb, but alternately rises and falls, to a diminishing extent with each reversal, till the same level is regained in each limb. So also, if a metal spring, held at one end in a vice, is pulled to one side and released, it will not regain its position of rest immediately, but will vibrate to and fro with constantly diminishing amplitude till it ceases to move.

Fig. 1.—Diagram representing oscillatory discharge of a condenser.

In the case of the condenser the frequency of the current reversal or oscillation may be high enough to deprive the current of its stimulating properties. The frequency may even far exceed this height, or, on the other hand, it may fall below it; in the latter case the current will regain its power to stimulate and become a "low-frequency" current. The conditions which decide whether the discharge of a condenser shall be *oscillatory*, and those that determine the *frequency* of the oscillation and its *duration*, will now be described.

Conditions necessary for an oscillatory discharge.—In order that the current accompanying the discharge of a condenser may alternate, two conditions must be fulfilled. In the first place, the resistance of the circuit along which the discharge takes place must be *low*. If it is high, the current will flow only in one direction. In the same way, sufficient narrowing of the bend of the U-tube will cause the mercury to regain the same level in each limb without any preliminary up-and-down movement. So, also, the immersion of the spring in viscid fluid will prevent vibration to and fro before the position of rest is regained.

The second condition which must be fulfilled, if the discharge is to be oscillatory, is that "self-induction" must be possible in the circuit; that is, the current flowing in the circuit must induce other currents *in the same circuit*. This can be effected by winding the circuit in the form of a spiral of one or more turns. Some self-induction, though very slight, is possible if the circuit is composed of a straight wire.[1]

If the coats of a charged Leyden jar are connected by a copper wire, the discharge will be oscillatory, because the wire has a low resistance and allows self-induction. If the human body is included in the circuit the resistance will be too high, and the discharge will be unidirectional; the current will not oscillate and the body will experience a shock.

Conditions determining the frequency of the oscillation.—The *frequency* of the oscillation, *i.e.* the number of reversals of the current per unit of time, depends upon three factors.

First, the resistance of the circuit. If the resistance is low enough to allow oscillation, the effect of further lowering is to increase the frequency of the oscillation, while if the resistance is increased the result is to lower the frequency. As already stated, if the resistance is increased beyond a certain magnitude the discharge ceases to be oscillatory and the current flows in one direction only. The analogous phenomena in the U-tube are seen when the latter is constricted at its bend. The resistance is thereby increased, and the effect is to diminish the number of rises and falls of the mercury in the limbs, while further narrowing of the bend will cause the mercury to reach the same level in the two limbs without any preliminary up-and-down movement.

Second, the amount of self-induction (inductance) in the circuit. If the self-induction is increased, as by winding the circuit in the form of a spiral of many closely adjacent turns, the frequency of the oscillation will be lowered. The lowering of the frequency by increasing the self-induction may be compared to loading a spring and thereby lessening the frequency of its vibration.

Third, the capacity of the condenser. The current from a condenser of large capacity will oscillate with lower fre-

[1] The term "inductance" is used to express self-induction. An inductance is a conductor in which self-induction can take place.

quency than that from a condenser of small capacity, the resistance of the circuit and its self-induction remaining the same. So, also, a longer spring will vibrate less frequently than a shorter spring of the same calibre.[1]

Conditions determining the duration of the oscillations.—The time occupied by the group of oscillations which occurs during the discharge of the condenser depends upon the same three factors which influence the frequency of the oscillation.

First, the resistance of the circuit. Increasing the resistance not only lowers the frequency of the oscillation but also shortens its duration. If the resistance exceeds a certain height there is no oscillation of the current, and the latter flows in one direction only. When the amplitude of each oscillation is smaller than that of its predecessor the oscillation is said to be "damped." It is said to be "strongly damped" when it is quickly reduced to zero, only a few oscillations taking place and each one being of much less amplitude than its predecessor. When there is no diminution of the amplitude of successive oscillations the latter are said to be "undamped." The damping of the oscillation may be compared to the vibration of a spring against resistance. If the latter is slight, the vibration is infrequent; if it is great, vibration will be prevented.

Second, the amount of self-induction. If this is increased the duration of the oscillation is lengthened.

Third, the capacity of the condensers. Increase of the capacity lengthens the duration of its discharge. Increasing the capacity of a condenser corresponds to lengthening of a spring and so lengthening the duration of its vibration.

The number of oscillations may be calculated from the resistance of the circuit, the amount of self-induction in the circuit, and the capacity of the condenser. The unit of self-induction is the *henry*, and is denoted by the letter L. It is the induction in a circuit when the E.M.F. induced in this circuit is 1 volt, while the inducing current varies at the rate of 1 ampere per second. The unit of capacity is the farad;

[1] By greatly enlarging the capacity of the condenser and increasing the amount of self-induction of the circuit, the frequency of the oscillation may be lowered sufficiently to cause the spark of discharge to emit a musical note.

it is denoted by the letter K. It is the capacity of a condenser, when the latter is charged to a potential of 1 volt by 1 ampere flowing for 1 second. As this is an extremely large capacity, one-millionth of it, known as a microfarad, is commonly used.

If the resistance of the circuit along which the condenser discharges is low the number of oscillations is nearly equal to $1 \div 2\pi\sqrt{KL}$, where K is the capacity of the condenser, measured in microfarads, and L the measure of the self-induction in the circuit in henries.

Thus, if the condenser has a capacity of $\frac{1}{300}$ microfarad, and the circuit along which it discharges has a self-induction of $\frac{1}{1000000}$ henry and a negligible resistance, the number of oscillations would be 1,061,000 per second. This represents the approximate frequency of the oscillation in a common form of d'Arsonval high-frequency current generator, in which the condenser, a Leyden jar of quart size and average dimensions, has the capacity above mentioned, and the circuit, a thick wire spiral of 21 turns, 3 in. in diameter, has the self-induction stated. This apparatus will be described later (p. 15).

The actual duration of the complete group of oscillations accompanying each discharge of a condenser can be calculated, but the calculation is very complex. The duration is, however, exceedingly brief. With the condenser and circuit mentioned above it has been calculated to be about $\frac{1}{500000}$ second.

CHAPTER IV

THE ORIGINAL HIGH-FREQUENCY CURRENT GENERATOR

In this chapter is described the original type of high-frequency current generator. Knowledge of its construction and working will facilitate the understanding of the more complex diathermy machine and explain why the current yielded by the former cannot produce much diathermy. A simple explanatory model of high-frequency current apparatus is described first, and, later, it is shown how the original apparatus can be modified so as to produce a current capable of yielding a fair degree of diathermy.

(1) *Simple Explanatory Model.*

The construction and working of the different types of high-frequency current generator will be more easily under-

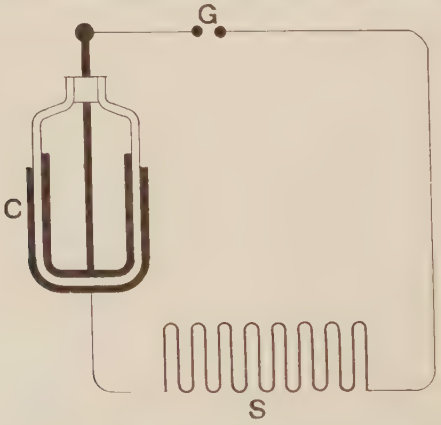

Fig. 2.—Plan showing connections of condenser (C), solenoid (S), and spark-gap (G). High-frequency currents can be produced in the circuit CSG.

stood by studying a very simple form of apparatus shown in plan in Fig. 2. It contains the three essential parts, viz. (1) a condenser, (2) a low-resistance coil which allows self-induction, and (3) a spark-gap.

C represents the condenser (Leyden jar). The circuit

connecting its coats contains a coil of thick wire (S). This coil is usually known as a "solenoid." In the circuit a gap (G) is introduced. It is known as the "spark-gap."

The condenser is charged by connecting its inner coat to some source of supply such as an electrical machine. A charge of the opposite kind is induced on the outer coat. As soon as the potential difference between these charges is sufficiently high a spark appears at the gap (G) and the condenser discharges. The current accompanying the discharge oscillates with high frequency between the outer coats along the circuit containing the solenoid and spark-gap.[1]

(2) *The d'Arsonval High-frequency Current Generator.*

A picture of a d'Arsonval high-frequency current generator for medical purposes is shown in Fig. 3. A plan which will explain the construction and working is shown in Fig. 4. It contains two *condensers* (Leyden jars), A and B. Their outer coats are connected by the *solenoid* (DE). This is a copper spiral containing about twenty turns of thick wire. The diameter of each turn is about three inches. The Leyden jars, solenoid and spark-gap constitute the so-called "d'Arsonval transformer."

The inner coats of the Leyden jars are connected to the secondary terminals of a large induction coil capable of giving at least a six-inch spark. The spark-gap (C) is situated between the end of two sliding rods which are in electrical connection with the inner coats of the jars. The width of the gap can be varied by means of the sliding rods.

The primary circuit of the induction coil is connected to a source of constant current (such as the main or a battery of accumulators), and the interrupter is set in operation. Sparks pass in very rapid succession across the gap (C). Each spark signals the discharge of the Leyden jars. At each discharge a current oscillates with high frequency between the inner coats of the jars across the spark-gap. At

[1] The actual resistance of the air-gap is very high, but when the discharge commences it produces a spark at the gap; this spark ionises the air momentarily and lowers its resistance sufficiently to allow a current to oscillate across it with high frequency.

the same time a current oscillates with the same frequency between the outer coats along the solenoid.

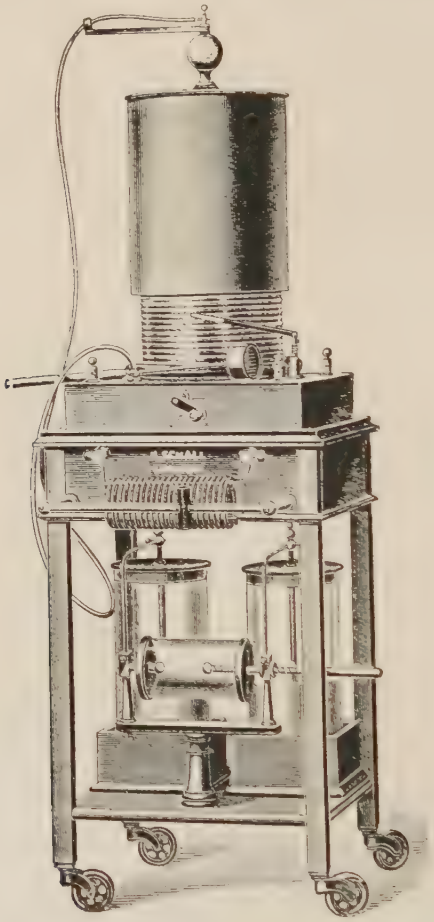

FIG. 3.—Early type of medical high-frequency current generator. The Leyden jars can be seen on the lower part of the pedestal. In front of them is the spark-gap enclosed in a glass chamber. The solenoid is seen on the front of the pedestal immediately above the Leyden jars. (The long coil of wire on the top of the pedestal is known as the "Oudin resonator." By its means the high-frequency current which oscillates in the solenoid can be made to produce another high-frequency current at higher voltage and lower amperage. This current oscillates in the Oudin resonator.)

The following events take place when the apparatus is in operation. At the moment when the primary current in the coil is interrupted a difference of potential is established between the secondary terminals

of the coil. The same difference of potential is established between the inner coats of the Leyden jars, one being charged positively and the other negatively. These charges neutralise each other across the spark-gap. At the same moment the charges which are induced on the outer coats of the jars neutralise each other along the solenoid.

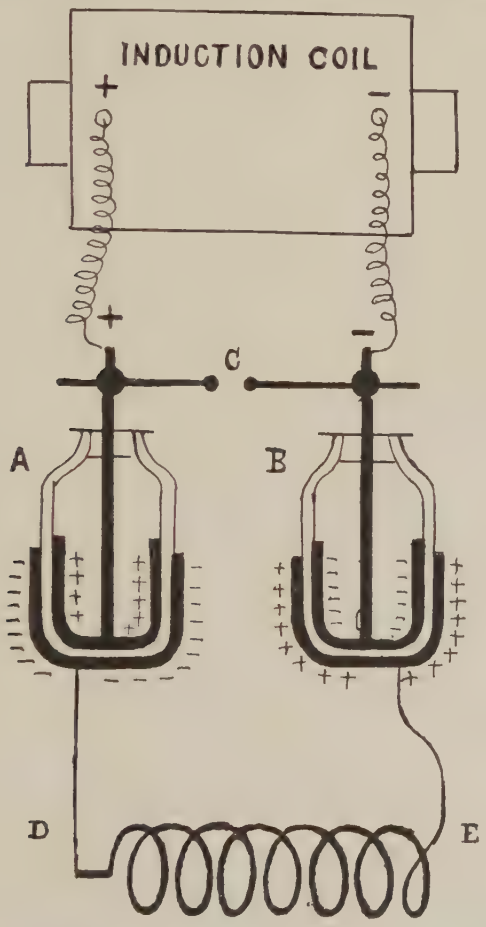

FIG. 4.—Plan showing connections of Leyden jars (A and B), solenoid (DE) and spark-gap (C) in the d'Arsonval apparatus.

At each interruption of the primary current the same events are repeated; the jars are charged, then discharged, and during the discharge a high-frequency current oscillates between the inner coats and another between the outer coats.

There is no high-frequency current at *make* of the current in the primary circuit of the coil, for although a difference of potential is

established between the terminals of the secondary coil, it is insufficient to allow the charges on the inner coats of the jars to neutralise each other across the spark-gap.

The current oscillating in the solenoid cannot be passed directly through the body. If the latter were included in the circuit containing the solenoid a high resistance would be added to the circuit and the current would not oscillate with high frequency. The body would then receive violent shocks. If, however, the patient is connected by cables to the outer coats of the jars or the ends of the solenoid it will be traversed by high-frequency currents and no shocks will be felt. When the body is connected in this way it might be thought that the current would pass almost entirely along the solenoid. This, however, is not the case. The actual resistance of the wire composing the solenoid is very low, not more than a small fraction of an ohm. But currents which oscillate with high frequency meet with great opposition in spiral circuits like the solenoid. This opposition is caused by the induction, in the same circuit, of other currents which pass in directions opposite to those of the inducing currents.[1] There is, consequently, very little current in the solenoid in spite of the difference of potential between the outer coats of the jars. Although the actual resistance of the body is much higher than that of the solenoid, the high-frequency current does not meet the same opposition in the tissues; hence the current passes almost entirely through the body.

The current from a generator of the kind described above produces very little diathermy. If it is passed through the body there is no sensation of heat until many minutes have elapsed; even at the end of twenty minutes the heat may be only just apparent. The apparatus does not generate high-

[1] When the high-frequency current commences its oscillation and flows in one direction along the solenoid it induces, *in the same circuit*, another current which flows *in the opposite direction*. This induced current is only of momentary duration, but before it stops, the inducing current reverses; it is then opposed by another induced current. The opposition of the inducing current by another self-induced current is repeated at each reversal. The low resistance necessary for an oscillatory discharge is the resistance of the circuit, *as offered to a constant current*, not the resistance due to opposition from induced currents. The term "impedance" is used to express the opposition encountered in a circuit by high-frequency currents.

frequency currents during the whole time it is connected to its source of supply, but only for a very small portion of it.

These currents are produced only while the jars are discharging. The time occupied by each discharge is exceedingly brief because the jars have a very small electrical capacity. After each discharge there is an interval of rest until the jars are again charged preparatory to their next discharge. The actual duration of this interval of rest depends on the rate of interruption of the primary circuit of the coil (the jars being charged at each interruption), but it is far longer than the time occupied by the discharge. Consequently the current-oscillation in the solenoid is not sustained, but lasts for very brief periods, each period being followed by an interval during which no oscillation takes place.[1]

By making certain modifications in the design of the d'Arsonval apparatus it is possible to obtain a high-frequency current capable of procuring more diathermy. The modified transformer will be described because it may be of use to those who possess long-spark induction coils.

(3) *The Modified d'Arsonval Transformer.*

An example of this type of high-frequency current generator is shown in Fig. 5. The essential differences between this and the original type are in the condensers and the spark-gap. The small-capacity Leyden jars are replaced by plate condensers of larger capacity. They are two in number, and each is made of sheets of metal separated by glass and immersed in oil. They are enclosed in the case mounted on the lower shelf of the pedestal as shown in Fig. 5.

The spark-gap is multiple, that is, it is subdivided into a series of gaps. There are nine in all. Each gap is situated

[1] The actual duration of the discharge of the Leyden jars depends on their capacity and the amount of self-induction produced in the solenoid. It may be as short as $\frac{1}{50000}$ sec. If the rate of interruption of the primary circuit is 100 per second, it follows that during each $\frac{1}{100}$ sec. the oscillation lasts only for $\frac{1}{50000}$ sec. Hence if the body is connected to the end of the solenoid it will be traversed by high-frequency currents for only $\frac{1}{500}$th of the time for which the machine is in operation.

between a pair of narrow metal discs. The discs are mounted on larger metal plates and are kept apart by mica washers $\frac{1}{16}$ inch thick, one of which is placed between each pair of plates. The width of each gap is therefore $\frac{1}{16}$ inch. The sparks have thus to pass across a total width of about $\frac{1}{2}$ inch.

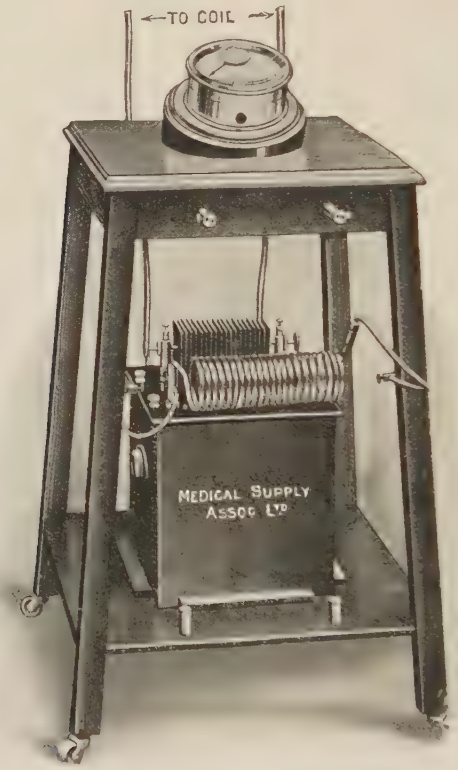

Fig. 5.—Modified type of d'Arsonval transformer.

The object of the multiple spark-gap is to prevent overheating. If a single gap of the same width were used a thick flame-like spark, or arc, would be present at the gap, and the resistance of the latter would be so low that the current from the induction coil would be short-circuited across it and the condensers would not be charged.

The solenoid is similar to that used in the original apparatus. It can be seen in the figure mounted on the cover

of the case containing the condensers. Behind it is the spark-gap. On the top of the pedestal is an ampere-meter of the hot-wire type. The condensers are charged by connecting them to a long-spark induction coil which is supplied with current from the main. The patient is connected to the ends of the solenoid.

A generator of the kind described above gives a larger output of current than the original apparatus. In the first place the condensers, having a larger capacity, hold a larger charge, and the high-frequency current which accompanies their discharge will last for a less brief period. In the second place the condensers, after being charged, will discharge across the spark-gap, not only at each "break" of the primary current, but also at each "make." The spark-gap, being narrow, will allow the condensers to discharge across it when charged to the relatively low potential induced between the secondary terminals of the coil when the primary current is "made." And since this difference of potential lasts longer than that induced at "break" of the primary it is likely that the condensers will be charged more than once at each "make" of the primary current. It is also possible that they may be charged more than once at each "break" of the primary current. If this is so they will be charged still more often at each "make" of the primary current.

If the primary current is interrupted 100 times per second there will be during each $\frac{1}{100}$ sec. not a single train of high-frequency oscillations of very brief duration, but three, four or more trains, each of longer duration.

As the total width of the spark-gap is less than that in the original machine, the voltage to which the condensers are charged is lower and the strength of the high-frequency current attains a higher average.

The degree of diathermy obtained from machines of the type described above seems to depend on the coil from which the condensers are charged. An old 8-inch spark coil which was fitted to the original high-frequency apparatus at St. Bartholomew's Hospital was used to charge the condensers of the modified apparatus, and the latter yielded a current capable of producing a fairly high degree of diathermy.

Other coils were less efficient for the purpose. It appears that those which are most suitable for X-ray work are not necessarily the best for use with the modified d'Arsonval transformer.

If the current from the main is *alternating* it can be led through a suitable rheostat to the primary circuit of the induction coil. The interrupter can then be put out of circuit. The modified transformer will then yield a current capable of producing a higher degree of diathermy than is possible when the primary coil is supplied from a source of *direct* current.

CHAPTER V

PRODUCTION OF CURRENTS YIELDING HIGHER DEGREES OF DIATHERMY

The general plan of construction of generators that can yield currents capable of producing higher degrees of diathermy, their method of working and the events that take place in the different parts of the machine are described in this chapter.

THE machines already described produce currents of which the oscillations occur in groups separated from each other by periods of rest in which no oscillation takes place. In other words, the oscillations are *unsustained*. The currents from these machines generate heat slowly. They may generate it so slowly that it is lost by radiation from the skin, by conduction into adjoining regions and by convection by way of the blood and lymph streams to distant parts of the body. Little or no local diathermy is produced. The modern diathermy machine is constructed with the object of producing currents of *sustained* oscillation. Such currents generate heat continuously. They can produce high degrees of local diathermy and cause a rise of temperature of the whole body.

Until comparatively recent times the nearest approach to success in the production of currents of sustained oscillation was made by altering the design and method of supply of the original high-frequency current generator, but retaining the same principle of production. Within recent years, however, new machines have been constructed. These work on a somewhat different plan and produce currents of which the oscillations are quite sustained. They contain a three-electrode thermionic valve and have no spark-gap. They have not yet come into general use. The principle on which they generate oscillatory currents will be described at the end of the present chapter. The plan of construction and the mode of working of the diathermy machine with a spark-gap will first be described.

Diathermy Machine with Spark-gap.

General plan of construction.—The diathermy machine contains a condenser, a metal spiral, a spark-gap and a step-up static transformer. By means of the latter the condenser is charged from the main. In comparison with the original d'Arsonval machine and its modifications the diathermy machine shows the following differences.

In place of the Leyden jars a single condenser is generally used. It is made of metal plates separated from one another by mica or other insulating material. It is charged from the secondary winding, not of an induction coil, but of a step-up static transformer. The latter consists of a mass of soft iron resembling, in shape, a picture frame or ring. On one side is wound the primary coil. This consists of a few turns of thick insulated wire. The secondary coil is composed of a large number of turns of thin well-insulated wire. It is usually wound over the primary coil.

In place of the solenoid is a flat spiral of metal resembling a clock spring. It is usually known as the "oscillator."

The spark-gap is very narrow. It is situated between metal discs. In some machines there is a single gap; in others there are two, three or more in series.

In most machines the patient is connected, not to the oscillator, but to a similar coil known as the "resonator." By means of the so-called "coupling device" it can be made to lie partially or completely over the oscillator without actually touching it.

The primary coil of the transformer is connected to the *alternating current* main. If the main supply is *direct*, a supply of alternating current can be obtained from it by means of a machine known as a rotary converter. In one machine (described on p. 49) a *direct current* is used and the condenser is charged directly to the same voltage as that of the main.

The static transformer, condenser, spark-gap, oscillator and resonator, and their connections are shown diagrammatically in Fig. 6.

AB is the primary coil of the transformer, CD is the

secondary coil; for the sake of clarity it is shown as if it were wound on the opposite side of the transformer.

F is the condenser. One set of its metal layers is con-

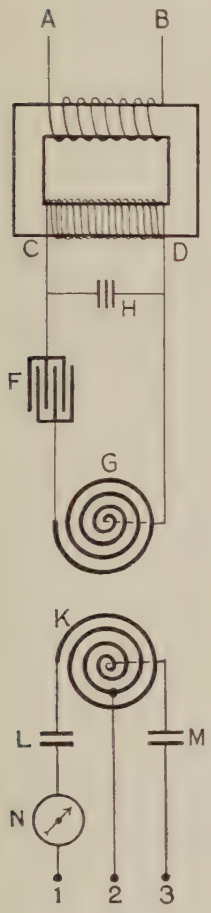

Fig. 6.—Plan of constituent parts of diathermy machine with spark-gap.

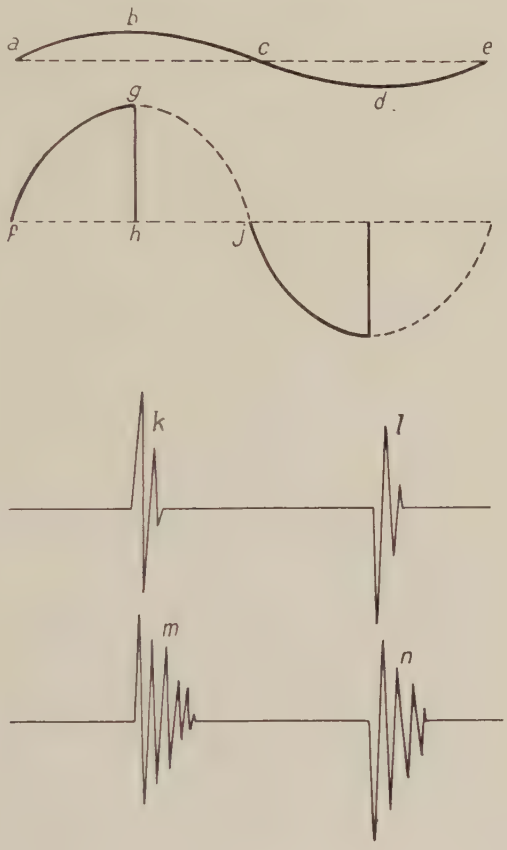

Fig. 7.—Diagram to explain events which take place in different parts of diathermy machine.

nected to one end (C) of the secondary coil of the transformer. The other set is connected to one end of the oscillator (G). The other end of the oscillator is connected to the end (D) of the secondary coil of the transformer.

H represents the spark-gap. The circuit containing the

condenser, oscillator and spark-gap is the same, in principle, as that shown in Fig. 2 (*q.v.*).

K is the resonator. Its extremities are connected to the terminals (1) and (3). There may be a third terminal (2), which is connected to some intermediate point along the resonator.

It is usual to insert a small condenser (L) between one end of the resonator and the terminal 1, and a similar condenser (M) between the other end of the resonator and the terminal 3. An amperemeter (N) is also inserted between one of these condensers and the terminal 1 or 3. Whether the patient is connected to 1 and 3, or to 1 and 2, the amperemeter will be in circuit with him.

The essential points of difference between the diathermy machine and the generators previously described are seen in the narrowness of the spark-gap and the use of a static transformer in place of an induction coil. In most diathermy machines the spark-gap is less than a millimetre. The condenser is therefore charged more often per unit of time and a larger number of groups of high-frequency oscillations are obtained. The secondary winding of a static transformer (the primary of which is supplied with alternating current) is a more constant and regular source from which to charge the condenser than the secondary winding of an induction coil (the primary of which is supplied with rhythmically interrupted current).

The current from a diathermy machine consists of groups of high-frequency oscillations following each other with very short intervals of rest (or, possibly, under certain conditions, without such intervals); the average voltage is low and the amperage high.

Events taking Place in Different Parts of the Diathermy Apparatus.

The current which alternates in the primary coil of the transformer creates, during each semiphase, a difference of potential between the ends of the secondary coil and the parts connected to them. The condenser is charged once (at least) during each semiphase and discharges across the

spark-gap. The current accompanying this discharge oscillates with high frequency along the circuit containing the oscillator. This current causes another to oscillate with high frequency in the resonator.

In Fig. 7 the curve *abcdc* represents a phase of the alternating current in the primary coil of the transformer. The current rises to its maximum (*ab*) and falls to zero (*bc*); *cdc* represents the completion of the phase in which the current flows in the opposite direction. The current in the primary coil cannot induce a similar (higher voltage) current in the secondary coil because the circuit in which this coil is placed is not continuous. The path CHD (Fig. 6) is interrupted at the spark-gap (H), and the path CFGD is interrupted by the condenser (F). The current in the primary, therefore, induces during each semiphase a difference of potential between opposite plates of the condenser, one set of plates being charged positively and the other negatively. As soon as the potential difference becomes sufficiently high the resistance of the spark-gap is overcome and the charged condenser discharges across it. The current accompanying the discharge oscillates with high frequency along the oscillator (G) and across the spark-gap. These events are represented schematically in Fig. 7. The curve from *f* to *g* represents the increasing potential difference, the maximum being attained at *g*. At this point the condenser discharges, and *k* represents the high-frequency alternating current accompanying the discharge. *m* represents the high-frequency current induced in the resonator.

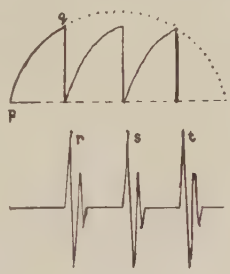

FIG. 8.

If the spark-gap is made narrower the condenser will discharge before the maximum difference of potential is reached. In Fig. 8 the condenser is represented as discharging when the potential difference has risen from zero (*p*) to *q*. The group of oscillations is indicated by *r*. Before the semiphase of the primary current has passed there is time for the condenser to be charged and discharged again. In Fig. 8 it is represented as being charged and discharged three times during the semiphase of the primary current. A group of high-frequency oscillations occurs at each discharge (*r*, *s*, *t*). By narrowing the spark-gap still further the condenser can be charged and discharged more often during each semiphase and more groups of oscillations can be obtained. But the more often the condenser is charged the lower will be the voltage to which it is charged; if the voltage is too low in proportion to the resistance of the circuit the amperage of the current will not be high enough to produce much heat in the tissues.

It has already been stated that by means of the coupling device the resonator can be moved in a plane closely parallel to that occupied by the oscillator. The current in the resonator attains its maximum value when this coil lies

completely over the oscillator. In this position the oscillator and resonator are said to be "tightly coupled." If the resonator lies less completely over the oscillator the current in it does not reach a maximum value. The coupling is then said to be "loose." If the resonator lies completely off the oscillator the coils are said to be "uncoupled"; there will then be no current in the resonator.

There are two ways in which a current, oscillating with high frequency, can cause another high-frequency current to appear in another suitably placed circuit. The first is by magnetic induction, the second is by "resonance." In regard to the first it can be understood that the varying magnetic field around the oscillator will induce currents in the resonator.

To understand the phenomenon of resonance it must be realised that a circuit, in which high-frequency currents are oscillating, is a source of electro-magnetic (Hertzian) waves, like those used in wireless telegraphy. These waves are propagated into space and are able to cause other high-frequency currents to oscillate in another circuit, which is suitably placed. The latter circuit is said to "resonate." In order that it may resonate it must contain a condenser, and it must allow self-induction to take place along it: in addition, the product of the capacity of the condenser and the amount of self-induction must be the same for oscillator and resonator. The latter will then resonate even if it is placed at a considerable distance from the oscillator, but if it is placed close to it, so as to lie in the magnetic field around the oscillator, the currents in the resonator will reach their strongest intensity. If the product of the capacity and self-induction is not the same for oscillator and resonator, but differs considerably, no resonance will take place, and currents of considerably less intensity will be induced in the resonator, these being due to the magnetic field around the oscillator.

In the diathermy machine the oscillating circuit contains the condenser F and the oscillator G (Fig. 6). The resonating circuit contains the two small condensers, L and M, and the resonator K. When the patient is connected to the terminals his body acts as an additional capacity. In the coil K the necessary self-induction takes place.

There is yet another requirement, if the current in the resonator is to be sustained and capable of producing much diathermy. The high-frequency currents in the resonator are also a source of electromagnetic waves. These may react on the waves propagated from the oscillator and interfere with them. The currents in the resonator will then be impeded or stopped. To prevent this, the high-frequency oscillations which accompany each discharge of the condenser in the oscillating circuit should be quickly suppressed or "damped," that is, reduced to zero after a very few alternations. The high-frequency current continues in the resonator after that in the oscillator has ceased, till it is reduced to zero by the resistance of the body.

This may be made clearer by an analogy. A pendulum is struck by a mallet and is made to swing. If the mallet is moved irregularly it may strike the swinging pendulum at the wrong moment and stop it or impede its swing. After each blow the mallet must stop (this corresponds to damping the alternations in the oscillator) until the pendulum ceases swinging (this corresponds to the cessation of the alternations in the resonator and body). Directly it ceases to swing a second blow must be given by the mallet (this corresponds to the next discharge of the condenser and the accompanying high-frequency current alternations in the oscillator).

The strongly damped oscillations in the oscillating circuit are shown diagrammatically in Fig. 7 (*k* and *l*). The more sustained oscillation in the resonator is shown in the same figure at *m* and *n*.

In order that the oscillations accompanying each discharge of the condenser may be quickly brought to zero (*i.e.* strongly damped) the spark-gap must be designed so that heat can be conducted away from it as rapidly as possible. The film of air or gas between the metal discs bounding the gap is made intensely hot by the first spark and becomes a conductor. If its temperature is not almost instantaneously lowered it will remain a conductor for too long a period, and the oscillation accompanying each discharge will not be brought to zero with sufficient quickness.

In the original d'Arsonval transformer the length of the spark-gap allows sufficiently rapid cooling of the air through which the sparks pass. In the modified transformer the same object is attained by subdividing the gap and allowing the sparks to pass between discs provided with radiators.

In the diathermy machine additional precautions are taken. The gap is bounded by broader discs and more metal is used. In some machines the sparks pass through coal gas or hydrogen.

It is doubtful whether diathermy machines containing spark-gaps yield currents of fully sustained oscillation. It is unlikely that the groups of oscillations accompanying each discharge of the condenser follow each other without delay. The current from these machines, however, is satisfactory for most purposes in diathermo-therapy. It is possible that the future may see the replacement of machines containing spark-gaps by others provided with a three-electrode thermionic valve. Though they are more costly they are highly efficient and the labour of attending to the spark-gap is saved.

Quite recently the high-frequency current has been used for the *excision* of neoplasms. For this purpose a current of sustained oscillation is required. Its most satisfactory source is a machine containing a three-electrode thermionic valve without a spark-gap.

For the reasons given above the principle on which high-frequency currents of sustained oscillation are obtained through the agency of the valve will now be explained.

Production of Sustained High-frequency Currents by Use of Three-electrode Valve.

The construction and working of the two-electrode and three-electrode thermionic valves must be understood before the part which the latter plays in the production of currents of sustained oscillation can be explained. In Fig. 9 (A) is shown a diagram of a two-electrode valve. It consists of a glass chamber from which the air has been completely removed. In the interior is a filament of fine tungsten wire (*a*) and a metal plate (*b*). Electrical currents cannot pass between the filament and the plate because a vacuum is an insulator. If, however, the filament is heated to incandescence, electrons (atoms of negative electricity) will be emitted from it and the interior of the chamber will become a conductor. But it will conduct *in one direction*

only, hence the description "valve." If the filament is connected to the *negative* side of the source of current and the plate to the *positive* side a current will pass through the valve. If the connections are reversed no current will pass. The filament is known as the "hot-wire electrode" or kathode; the metal plate is known as the "plate electrode" or anode.

In Fig. 9 (B) is shown a diagram of a three-electrode valve. The kathode and anode are the same as those in the two-electrode valve. In addition the so-called "grid" (*c*) is placed between the anode and kathode. It consists of a perforated metal plate resembling a sieve. Suppose, now, that the valve is conducting a current. If the grid is rendered electrically positive from some external source the current through the valve will be increased. If, on the other hand, it is rendered negative the current through the valve will be reduced or even stopped. Only small charges are needed on the grid either to increase or stop the current through the valve. If the grid is made alternately positive and negative, the current through the valve will be made alternatively stronger and weaker. If the grid is sufficiently negative, the current will become intermittent and pass only when the grid is positive.

The grid can be made alternately positive and negative (the charges changing their sign with high frequency) by connecting it to one of the two plates of a discharging condenser. The current passing through the valve can be made intermittent (with the same frequency of interruption) or made to wax and wane with the same frequency.

In Fig. 9 (C) *d* represents a source of constant current at high potential. The current can pass (when the filament is incandescent) through the valve, from filament to plate, along the coil *g* and back to its source. A condenser is represented at *e*. At *f* is represented a coil (inductance) along which the condenser can discharge after it has been charged. One of its plates is connected to the grid, and the other to the filament.

Suppose, now, that the condenser is charged. It will discharge with high frequency along the coil *f*. At the same time, while it is discharging, the grid will be alter-

natively negative and positive. As a result the current passing from d through the valve and the spiral g will be made to wax and wane with the same frequency until the condenser is discharged; it will then resume its constant strength. Now if the coil g is placed a little distance from

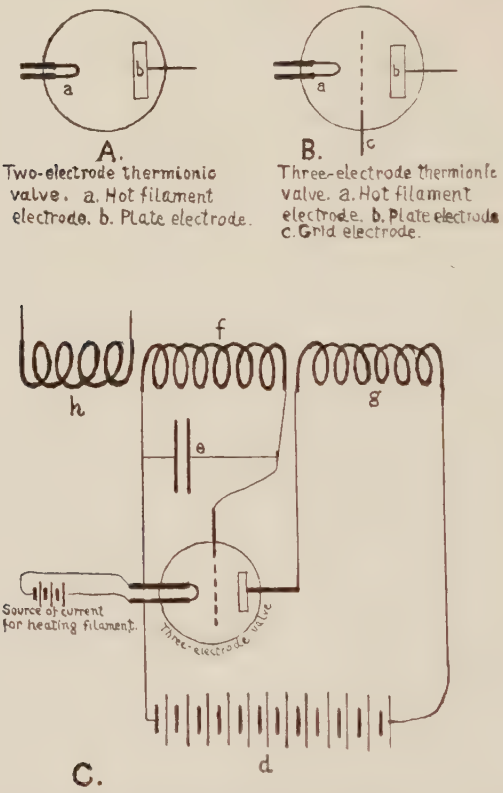

Fig. 9.—A. Two-electrode thermionic valve. B. Three-electrode thermionic valve. C. Diagram to show connection of parts to obtain sustained high-frequency oscillations.

f the oscillation in f will not die away. The current in g will induce currents in f. If they are induced at the correct moments they will flow in the same directions as those accompanying the discharge of the condenser. With each change of direction of the current in f it will not grow weaker, because there will be added to it the current induced

in f from g. If g is placed close to f the current in the latter can be greatly increased. In other words, the oscillation in f can not only be sustained but increased or *amplified*.

The initial charge of the condenser need only be infinitesimally small and may be derived from electrical disturbances in the ether. However weak may be the initial oscillation in f, it can be amplified to a degree sufficient to procure diathermy in a subject connected to the ends of the coil f, or to a similar coil h suitably coupled to f.

The current which passes through the valve and along the coil g must be at high voltage. It is derived from the secondary winding of a static transformer as in diathermy machines with spark-gaps. The primary winding is supplied with current from the AC main. The current induced in the secondary winding is alternating. By means of a suitable rectifier combined with condensers it is made unidirectional and, as near as possible, constant.

The plan of the actual machine is considerably more complex than that shown in Fig. 9 (C). The latter has been made as simple as possible for explanatory purposes.

A diathermy machine containing a three-plate valve is shown in Fig. 37, and its plan in Fig. 38.

CHAPTER VI

THE DIATHERMY MACHINE

The present chapter has been written in order to acquaint the reader with the structure of the diathermy machine in its various forms and indicate the essentially distinctive features of the various makes that are now available. The large majority contain a spark-gap, and these will be described first. Some notes are added on accessory apparatus and the care of the machine.

Diathermy machines are made in various sizes. Small models are intended for surgical work only. These generate small currents and do not require a large current of supply. One of these—the Canny-Ryall machine—is described on p. 59. Some of the small machines are made for *minor* surgical work only, such as the destruction of papillomata of the urinary bladder (see p. 53, Schall's smallest model).

Diathermy machines of medium size provide larger currents suitable both for medical and surgical work. These are most generally useful. Machines of this kind are the A. E. Dean model (p. 35), the "Equator" (p. 39), the Watson "Standard" (p. 42), the "Portable" (p. 49), the "Universal" (p. 47), the "Holway" (p. 54), the "Thermo." (p. 55) and the "Taunton" (p. 56).

Diathermy machines of large size are constructed. These are used by a few workers for the treatment of more than one patient at the same time. One of these is described on p. 44 (the "Power" model). Another, the "Therapeutic" model (p. 46) is intermediate in size between the medium and large sizes.

Some machines by German, French and American makers are also described in brief (pp. 60–72). A machine containing a thermionic valve is shown on p. 72. It is of Dutch manufacture (Nederlandsche Seintoestellen Fabriek).

1. Machine by A. E. Dean.

This is shown in Fig. 10. The front of the cabinet has been removed and the static transformer can be seen. On the top of the cabinet can be seen the amperemeter; behind this is the spark-gap covered by a metal hood. The various

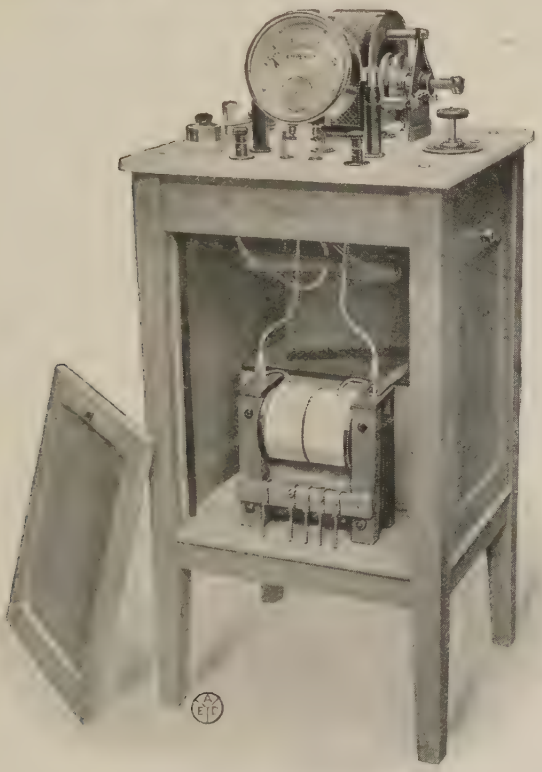

Fig. 10.—Diathermy machine by A. E. Dean.

parts of the machine and their connections are shown in Fig. 11. C is the primary coil of the transformer. E is the secondary coil and D is the iron core. The condenser is enclosed in the case F. It is made of metal sheets separated from each other by glass. It is immersed in oil.

The parts constituting the spark-gap are shown at G. There are three air-gaps in series. They are bounded by

copper discs which are placed face to face, very close together, but are prevented from making contact by means of mica washers. The broad circular plates shown in the figure are

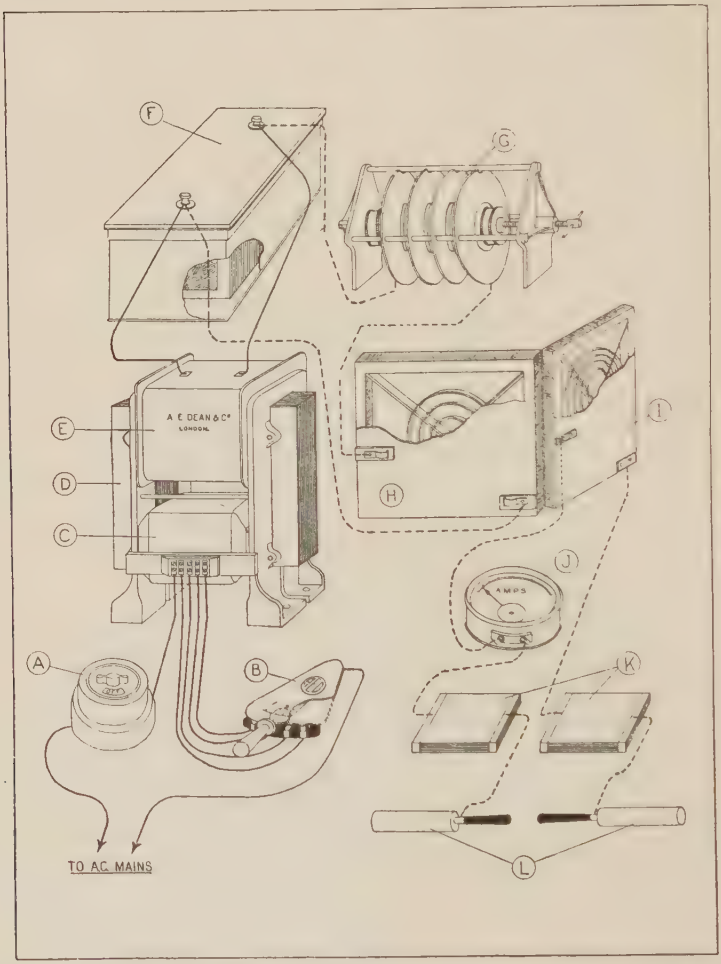

Fig. 11.—Component parts of the diathermy machine shown in Fig. 10 and their connections.

metal fins which are inserted in order to prevent overheating of the copper discs. The construction of the spark-gap can be more easily understood from Fig. 12, which shows it diagrammatically in section. In this figure two air-gaps only

are shown. The copper discs are shown at *e*, *f*, *g* and *h*, and the cooling fins at *j*, *k* and *l*. A mica washer is placed between *e* and *f*, and another between *g* and *h* (they are not shown in the figure). These washers have the same external diameter as the copper discs and are about half a millimetre thick. *m* and *n* are thick discs of glass or china. By means of the screw *o* the copper discs, metal fins and mica washers are pressed into contact and maintained in position.

The condenser discharges across the air spaces between *e* and *f*, and *g* and *h*. The width of each space is equal to the thickness of the mica washer. If desired the width can

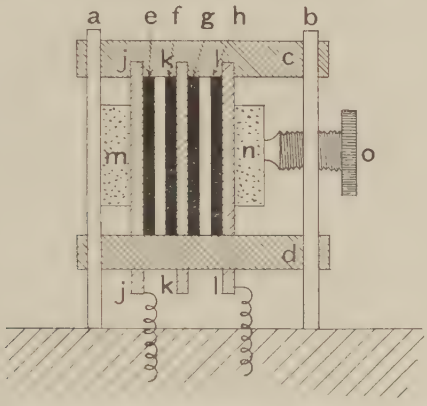

FIG. 12.—Diagram of spark-gap fitted to Dean's diathermy machine.

be increased by inserting more washers. Those parts of the copper discs between which the sparks pass are faced with silver. The rods *c* and *d* are made of insulating material and serve to support the copper discs, cooling fins and mica washers. These rods and the discs *m* and *n* insulate the current accompanying the discharge of the condenser from the framework of the spark-gap. The hood which covers the spark-gap (Fig. 10) is shaped like an inverted U. To its free ends are fixed metal pegs which fit into metal sockets on the top of the cabinet. When the hood is removed the circuit of the incoming current is interrupted. The spark-gap can then be examined and adjusted without fear of shocks or burns.

The case H (Fig. 11) contains the oscillator. The latter

is a flat copper spiral and resembles a clock spring. The side of the case has been partially removed to show a portion of the oscillator.

The resonator is shown in part in the case I. It resembles the oscillator but contains more turns. In the assembled machine the case containing the resonator is movable. By rotating the coupling handle shown in Fig. 10 on the top of the cabinet on the right-hand side it can be made to slide from side to side and lie partly or wholly in front of the case containing the oscillator.

The amperemeter is shown at J. It is of the hot-wire type. The current passing through it heats a fine wire which then lengthens. The increase in length is indicated by a recording needle which moves over a scale. The scale has previously been calibrated by passing galvanic currents of known strength along the fine wire.

Two electrodes are shown at L. Two small condensers are shown at K. These are placed in the circuit containing the resonator and electrodes. The amperemeter is also included in this circuit.

A special feature of this machine is the method adopted for regulating the incoming current from the AC main. The primary coil of the transformer is subdivided into four parts. By means of the collector (B, Fig. 11) the current from the main can be taken through one, two or more divisions of the primary coil. The latter takes least current when one division is included in the circuit.

The machine yields its maximum diathermy current when four divisions of the primary coil are included in the circuit and the oscillator and resonator are "tightly coupled," that is, when they lie in parallel planes and in close apposition without contact. By moving the resonator away from the oscillator ("loose coupling") the current is diminished. The current can also be diminished by excluding one or more divisions of the primary coil of the transformer from the circuit containing the incoming current.

The spark-gap above described is one of the "open" type. In this type the sparks pass through the atmospheric gases. In the "closed" type the air is excluded from the gap and its place is taken by coal gas or hydrogen.

The machine made by A. E. Dean & Co. can be fitted with a spark-gap of the closed type containing coal gas. This spark-gap resembles that fitted to Watson's diathermy machines. This gap is described on p. 42.

The transformer in the machine above described is wound so that the voltage of the current induced in the secondary coil is stepped up to about 8,000 when the primary coil is taking its maximum current. The condenser in the circuit containing the secondary coil has a capacity of about 0·006 microfarad. The inductance of the oscillator is, roughly, 20 microhenries and that of the resonator is from 60 to 70 microhenries. Each of the condensers included in the resonator circuit has a capacity of about 0·0001 microfarad. The frequency of the current in the patient's circuit is about one million per second.

2. The "Equator" Diathermy Machine.

(Medical Supply Association.)

This machine is illustrated in Fig. 13. The current from the main is led to the terminals shown on the front of the cabinet (left side). This current is not regulated by the operator. The condenser is made of metal plates insulated by paper impregnated with paraffin wax.

The spark-gap is shown in diagram in Fig. 14. It is of the "closed" type and the air is replaced by coal gas. It consists of two metal chambers A and A′; the tops of these are formed of mica discs. Passing through each mica disc is a stout screw (D and D′). To the inner end of each screw is attached a copper block. By rotating the screw the copper can be brought into close proximity to another copper block attached to the base of each chamber. The sparks pass across the spaces between the copper blocks. The width of the spaces can be varied by turning the screws D and D′.

The chambers are connected by means of a rubber tube. A stream of coal gas is passed through them by way of an inlet tube F, the connecting tube and the outlet tube G. A metal strip H brings the screws D and D′ into electrical connection.

The spark-gap is seen in Fig. 13 on the top of the cabinet. Metal fins are attached to the top of each screw in order to prevent overheating of the latter. They are not shown in Fig. 14.

An oscillator and resonator are enclosed in the cabinet. The current received by the patient is regulated by varying

Fig. 13.—" Equator " diathermy machine.

the coupling between the oscillator and resonator. This is effected by means of the coupling handle attached to the right side of the cabinet.

The following report on the " Equator " diathermy machine was issued by the Faraday House Testing Laboratory on April 12, 1926.

" The diathermy apparatus submitted was connected to

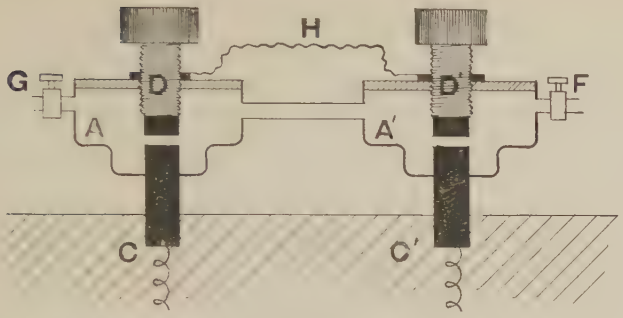

FIG. 14.—Spark-gap fitted to the "Equator" diathermy machine (diagrammatic).

FIG. 15.—"Standard" diathermy machine.

a 220-volt alternating circuit, frequency 50, and the pressure across the high-tension terminals was measured, with the apparatus working the two spark-gaps in series. This was found to be 3,600 volts. The frequency of the diathermy current was measured and found to be 667,000 cycles per second. The capacity of the condenser in the oscillating circuit, which consisted of two condensers in series, was measured and found to be 0·0054 microfarad."

3. Diathermy Machines by Watson and Sons.

Watson and Sons construct three distinct models of diathermy machine, one of medium size (Standard Model), one of large size (Power Model), and one which is intermediate in size between the other two (Therapeutic Model).

(a) *Standard Model.*—This is illustrated in Fig. 15. The cabinet has perforated metal sides. In its lower half the static transformer can be seen. In the upper half are the condensers, oscillator and resonator. The top of the cabinet is made of marble and on it are mounted the amperemeter and spark-gap. The latter is of special design. It can be seen on the right side of the amperemeter.

The primary winding of the transformer is tapped so that the current supplying the machine can be taken through part of the winding or through the whole. A crank for the purpose can be seen on the top of the cabinet on the left side in front. The secondary coil of the transformer is wound so that the current induced in it has a voltage of 5,000. The main condenser is composed of thin zinc plates separated by sheets of glass. It has a capacity of 0·005 microfarad.

The spark-gap is shown in diagram in Fig. 16. The spaces across which the sparks pass are two in number. They lie between a metal disc *ab* and two metal electrodes *c* and *d*. The two latter are fixed, and the disc is movable. By turning the ebonite handle *h* the disc can be raised or lowered, thereby widening or narrowing the spaces between the electrodes and the disc. The spark-gap is enclosed in a cylindrical chamber of aluminium. Each end of the cylinder is closed by an aluminium ring fitted with a mica centre.

Through the mica centres pass the electrodes so that the latter are insulated from the metal chamber. Radiating fins (not shown in the figure) are attached to the electrodes to prevent overheating.

The air of the chamber is replaced by coal gas or vapour of petrol or acetone. Taps for entry and exit of the gas are shown at *f* and *g*. If gas is unobtainable a little acetone or petrol is placed in the chamber. It evaporates and replaces the air from the chamber. The taps *f* and *g* are then closed.

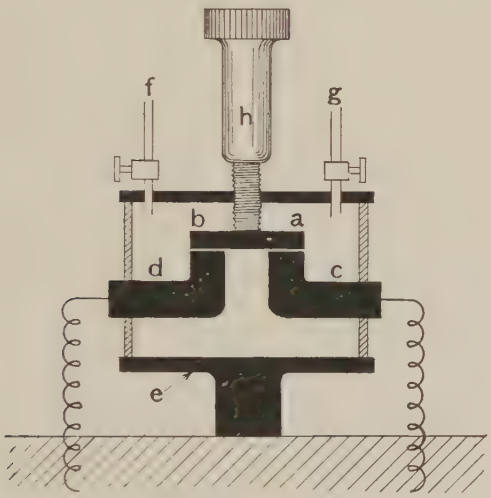

FIG. 16.—Spark-gap fitted to diathermy machines by Watson and Sons (diagrammatic).

The metal surfaces between which the sparks pass are faced with silver.

The oscillator is a spiral coil of thick wire. The resonator is similar, but the turns have a smaller diameter. By rotating the coupling handle (seen in Fig. 15, in front of the amperemeter) the resonator can be made to slide into the oscillator, both spirals having the same long axis. In this way the current in the resonator can be increased from zero to maximum. The circuit containing the resonator includes the amperemeter and two small condensers. The latter are similar in design to the main condenser. Each

has a capacity of 0·003 microfarad. These condensers are in series with the patient and the resonator.

The current yielded by this machine has a frequency of 850,000 cycles per second.

This machine can be connected to a Tesla transformer and used for producing a high-frequency effluve. A connecting link is provided so that the primary coil of the transformer can be introduced into the oscillating circuit (*i.e.* the circuit containing the oscillator, secondary coil of transformer and spark-gap) of the diathermy machine.

(b) *Power Model.*—This is a larger machine than the

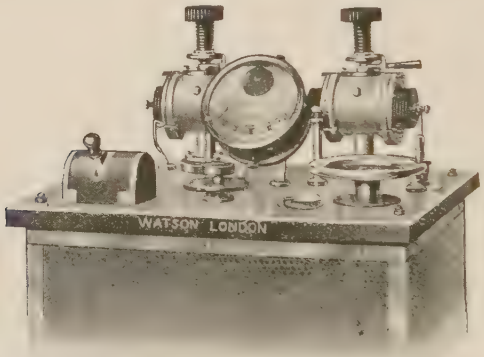

Fig. 17.—"Power" diathermy machine. (Upper part only is shown.)

Standard Model. It is shown in Fig. 17. It contains two spark-gaps and condensers of larger capacity. Different methods are adopted for regulating the incoming and outgoing currents. The plan is shown in Fig. 18.

Between the primary coil of the transformer and the main are introduced two additional coils, one in parallel (AB, Fig. 18) and the other in series (CD). The number of turns introduced can be varied. The coil introduced in parallel is known as an "auto-transformer" and consists of a single layer of wire wound around a laminated iron core. By varying the number of coils the voltage of the current passing along the primary winding (EF) of the static transformer can be adjusted. The coil introduced in series

is a "choke coil." By altering the number of turns introduced the amount of self-induction (inductance) which takes place in the primary winding of the transformer can be varied. By these methods the incoming current can be regulated through a necessarily wide range. In the secondary winding (GH) of the transformer a current is induced at a voltage of 5,000. The main condenser (K) is made of sheets of tinfoil separated by waxed paper. It is immersed in oil. It has a capacity of 0·007 microfarad. Two spark-gaps (L and L′) are used. Each is similar to that fitted to the Standard Model. They are placed in series.

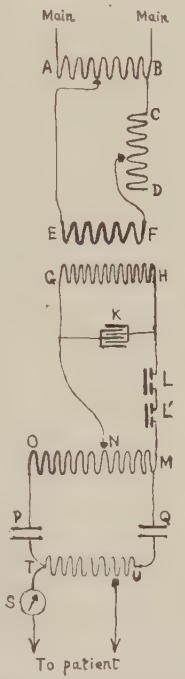

FIG. 18.—Explanatory plan of Power Model.

In the circuit containing the secondary coil of the transformer, the condenser and spark-gaps a high-frequency current is generated. The oscillator consists of a few turns of thick wire (MN) wound round a former which is 6 inches in diameter. Unlike the machines previously described the resonator is in direct continuation with the oscillator. It is constituted by the coil NO. The current in the resonator is the diathermy current which passes to the patient. It is led off by way of two wires, one of which is connected to the end O of the resonator, the other to N. In the patient's circuit are two condensers, P and Q. They are similar to the main condenser K and are immersed in oil. Each has a capacity of 0·006 microfarad. The amperemeter S is inserted in the patient's circuit.

The current passing to the patient is regulated by means of the wire coil TU. This coil is inserted in parallel across the wires leading the current to the patient's terminals. Presenting, as it does, a very high resistance to oscillatory currents, the current in the resonator passes almost wholly

to the patient. If, however, one of the wires passing to the patient is connected, not to one end of the coil TU but to some intermediate point, some of this high-resistance coil is now in series with the patient and the current passing to him will be reduced. The coil TU is composed of about twenty spaced turns of bare wire wound on a hollow drum. The drum is geared to the handle seen in Fig. 17 on the top of the cabinet in front (right side) and a variable contact is arranged so as to bear on the wire spiral (TU in Fig. 18). By turning the handle the drum is rotated and the variable contact travels along the coil TU. By this method as many turns as desired can be placed in series with the patient and the strength of the current regulated as required.

The current yielded by this machine has a frequency of 1,000,000 cycles per second.

The output of the Power Model is stated by the makers to be 100 per cent. more than that of the Standard Model. The supply current is correspondingly greater, the maximum input for the Standard Model being 650 volt-amperes, and that for the Power Model being 1,700 volt-amperes. The latter can, however, be reduced when light work is performed and only a small output is necessary. There is consequently no unnecessary waste of primary energy.

(c) *Therapeutic Model.*—This is a combination of the Standard and Power Models. The circuit is similar to that shown in Fig. 18, except that the current passing to the patient is regulated by moving the contact N (Fig. 18) along the coil OM. The coil TU is absent. A single spark-gap is used as in the Standard Model. The main condenser is the same as that fitted to the Standard Model. The small condensers in the patient's circuit are made of metal sheets separated by plate glass and each has a capacity of 0·003 microfarad.

Both in this machine and the Power Model a link connection is provided so that a Tesla transformer can be attached for production of high-frequency effluve.

4. Diathermy Machines by Schall.

The firm of Schall and Son make three models of diathermy machine. One of these, the "Universal," is of medium size and is suitable both for medical and surgical work. The

FIG. 19.—The "Universal" diathermy machine.

second is smaller in size and is *portable*. It is suitable for surgical and minor medical work. The third is quite small, weighing 36 lbs. It is suitable for minor surgical work only. The second model derives its supply from a *direct*

current main. It weighs 62 lbs. The Universal machine weighs 280 lbs.

The original form of diathermy machine used in England was by Schall. This was used at St. Bartholomew's in 1909. It was fitted with a spark-gap designed by Baron Le Pel. It consisted of metal discs separated by paper washers, of which the central opening was small. During passage of the sparks the paper was slowly charred away. The charring commenced at the edges of the central opening and proceeded towards the periphery. Frequent renewals of the paper washers were necessary.

(a) "*Universal*" *Machine.*—This is illustrated in Fig. 19. It derives its supply from the AC main. In the secondary coil of the transformer the voltage is raised to 2000. The condenser is made of metal sheets separated by glass. Its capacity is 0·005 microfarad.

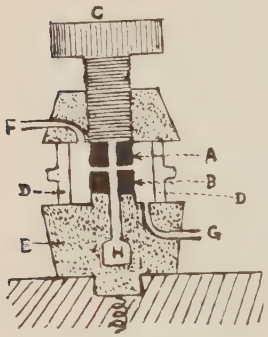

Fig. 20.—Vertical section of spark-gap fitted to "Universal" Model (diagrammatic).

The spark-gap is of distinctive design. It is constructed in two portions, each being identical. They can be seen in Fig. 19, mounted on the hinder part of the marble slab forming the top of the cabinet. The design of the spark-gap will be more easily understood from Fig. 20, which shows the parts diagrammatically in section. The narrow space across which the sparks pass is situated between two copper blocks, A and B. The upper block is attached to a finely threaded screw C so that its distance from the lower block can be adjusted and the width of the gap varied. D is a porcelain ring. This supports the metal block containing the screw C and insulates it from the lower block E. The latter is fixed. The upper block containing the screw can be lifted off for cleaning. When the machine is in operation the upper block is maintained in position by bolts. By means of the inlet and outlet pipes, F and G, a stream of coal gas can be passed through the spark-gap.

In places where coal gas is unobtainable methylated spirit can be used. The spirit is stored in a small reservoir. This can be seen in Fig. 19, behind the switch. Spirit passes from it into the small chamber H (Fig. 20), thence by capillary action along a wick in the channel above the chamber into the narrow space between the copper blocks A and B. The heat of the sparks vapourises the spirit and decomposes it, forming hydrogen. This gas occupies the space between the blocks. It is a good conductor of heat and prevents the blocks from becoming too hot.

The oscillator consists of a cylindrical spiral of insulated wire with the turns in close proximity. There is no separate resonator. The diathermy current for therapeutic use is taken from the oscillator. Wires are attached to the oscillator spiral at intervals along its course. These wires are brought into connection with metal studs secured to the marble top of the cabinet. One of the wires is attached to one end of the oscillator spiral and leads to one of the terminals to which the patient's electrodes are connected. The other terminal can be brought into connection with any one of the metal studs by rotating the crank lying within the glass cover seen on the marble slab in front (left side). It can thus be brought into connection with various points along the oscillator. The greater the length of oscillator spiral included in the patient's circuit the stronger the current and *vice versa*. In this way the current can be varied.

By means of the crank enclosed in the glass chamber seen on the right side of the marble slab in front (Fig. 19), additional condensers can be introduced into the oscillating circuit, thereby increasing the capacity of the main condenser. By this means a stronger current can be delivered to the patient when the body circuit is lengthy and has a high resistance.

(b) *Portable Model.*—This is shown in Fig. 21. Unlike the machines previously described it is supplied from the *direct-current* main. The voltage of the latter must be 200.

In this machine there is no transformer, and the condenser is charged directly from the main. The condenser discharges across a spark-gap and along a primary solenoid (oscillator).

The high-frequency current utilised for treatment is taken from a secondary solenoid (resonator); the ends of the latter are connected to the two outermost terminals seen on the right side of the marble slab forming the top of the case. The two middle terminals are connected to intermediate points of the resonator. By means of an electro-magnet the current, which is taken from the main, is automatically

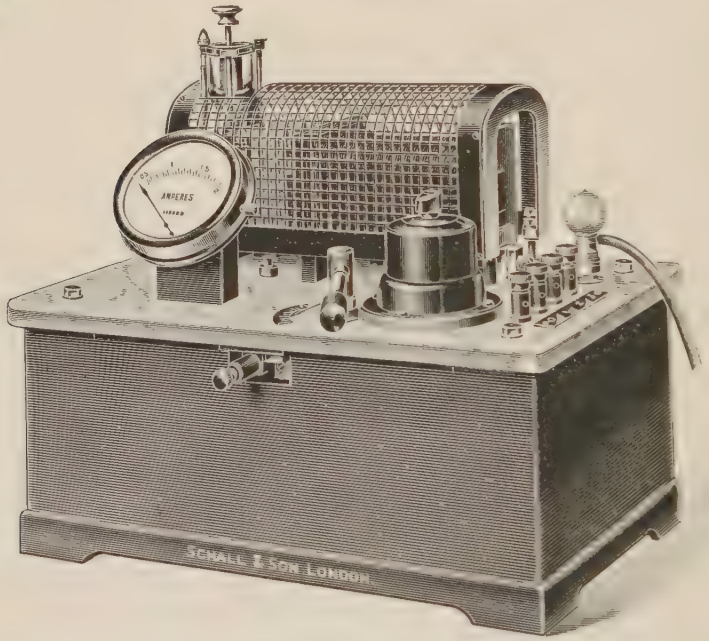

Fig. 21.—Portable Model diathermy machine for use on *direct-current* main.

short-circuited the moment the condenser is charged. The latter then discharges across the spark-gap and along the solenoid. The short circuit is then interrupted and the condenser is again charged. This alternate charging of the condenser and short-circuiting of the charging current, discharging of the condenser and interruption of the short-circuit, proceeds continuously. It is effected by means of the electro-magnet and an interrupter. The electro-magnet is under the wire network hood seen on the marble slab. The air of the spark-gap is replaced by methylated spirit

supplied from the small glass vessel (seen on the top of the hood) or by coal gas. Coal gas is better than spirit. It is led to the gap by way of a metal pipe and burnt as it escapes

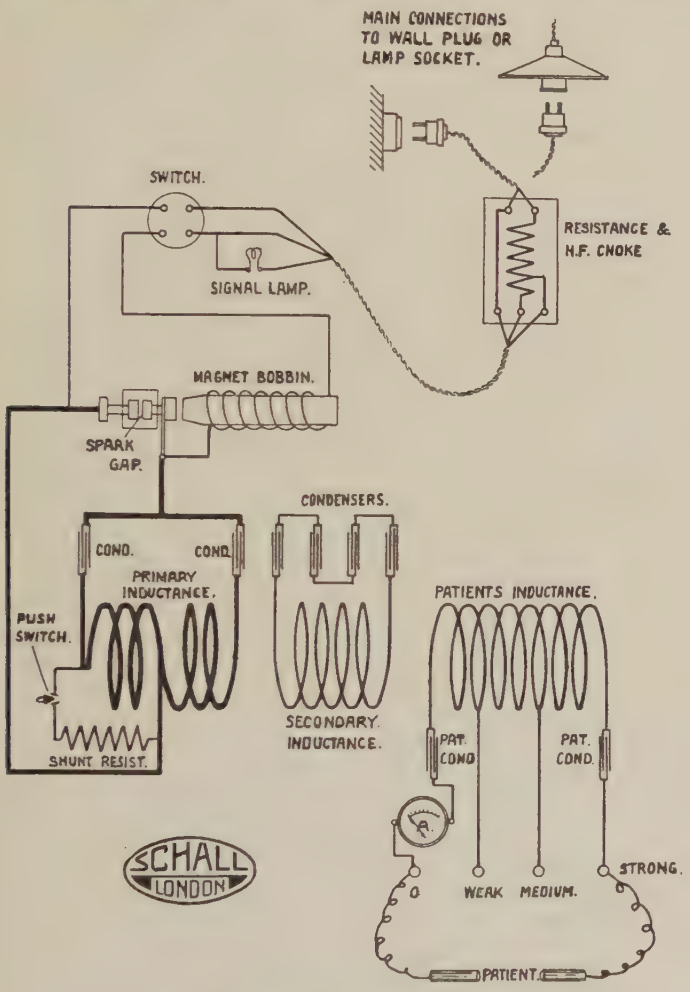

Fig. 22.—Plan of diathermy machine illustrated in Fig. 21.

from a narrow tube by the side of the glass vessel. By means of an ebonite screw at the left side of the metal hood (hidden from view in the figure), the width of the spark-gap is regulated. On the front of the marble slab is seen a

large switch, which, when opened, allows the main current to charge the condenser. On the left of the switch is the coupling handle, which brings the resonator over the primary solenoid. A small pilot lamp is seen on the right of the marble slab. When the switch is opened and the width of the spark-gap made sufficiently narrow by means of the ebonite screw, a rumbling sound, caused by the discharges of the condenser and vibration of the interrupter, is heard, and the filament of the pilot lamp becomes dull red. If the spark-gap is too narrow the rumbling sound ceases and the pilot lamp glows brightly. The condenser then is not charged. If the gap is too wide there will be no sound and the lamp filament will remain cold and the condenser will not discharge. In the original machine the ebonite screw required constant attention, as the noise of the discharge frequently ceased, and then the pilot lamp glowed brightly. This objection seems now to have been removed, and the makers claim that the gap requires no attention after adjustment. (See Fig. 22 for plan of this machine.)

(c) *Small Model for Intra-vesical Work.*—This is shown in Fig. 23. It provides a current sufficient only for the destruction of papillomata of the urinary bladder and small masses of tissue. It requires only a small supply current (alternating), and the latter may be derived either from the main or from a Pantostat machine if one is available.[1]

[1] Schall and Son have recently constructed a new model of diathermy machine (Fig. 24). It is of medium size. The parts are assembled in two cabinets. One of these (the lowermost in Fig. 24) contains the static transformer. The remaining parts are enclosed within, or mounted on, the upper cabinet. When the latter is placed on the lower cabinet, as shown in the figure, the connections between the transformer and the other parts are automatically made. Each cabinet is provided with a strap-handle by which it can be carried from the owner's house to a car and conveyed where desired. In this sense the machine is portable. The spark-gap is of the multiple "open" type. There are four gaps in series, and the air spaces across which the sparks pass are bounded by tungsten discs. The machine is supplied with alternating current from the main or a rotary converter and is constructed so as to take current either at 160 volts, 150 volts or higher. The five terminals seen on the top of the upper cabinet are connected to the ends and three intermediate points of the resonator. The voltage of the current received by the patient can therefore be varied within wide limits. The current derived from the outermost terminals can attain a voltage much higher than is possible in machines of the same size and can spark across an air space of an inch.

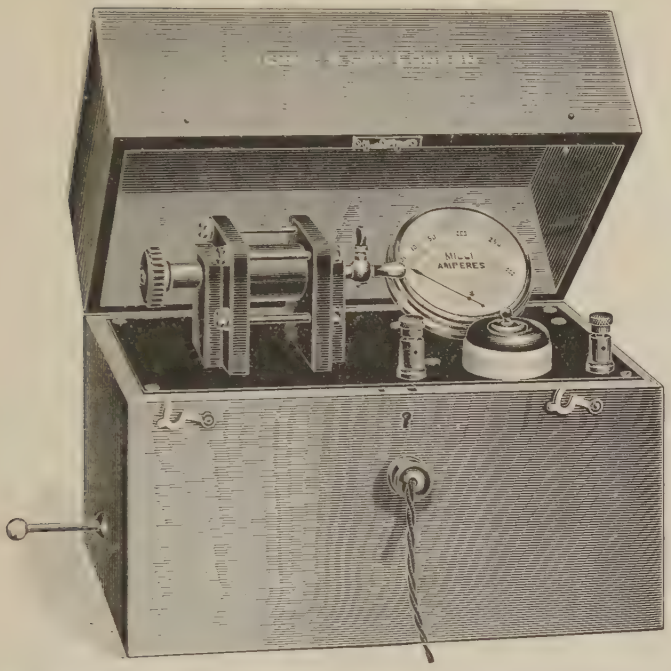

FIG. 23.—Small portable diathermy machine for minor surgical work.

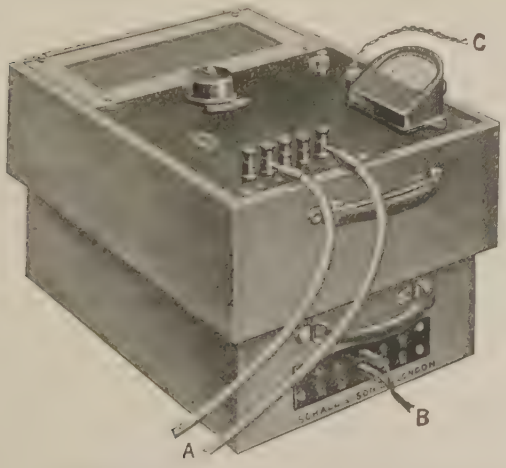

FIG. 24.—Schall's most recent model of diathermy machine.

The "Holway" Diathermy Machine.

(Newton and Wright, Ltd.)

This machine is illustrated in Fig. 25. The condenser consists of metal sheets separated by glass plates. It is immersed in oil and has a capacity of 0·0015 microfarad. It is charged from the secondary coil of a static transformer.

Fig. 25.—"Holway" diathermy machine.

In the latter the voltage is stepped up to 2,000. The spark-gap is enclosed in an atmosphere of coal gas. It contains a heavily silvered copper disc which bridges over the space between a pair of silvered copper blocks. In this way two spaces are formed and the sparks pass across them in series. The width of the spaces can be regulated while the machine is in operation. The spark-gap can be seen in Fig. 25 on

the right side of the top of the cabinet. It is extensively ribbed on the outside in order to prevent over-heating. It is covered by a protecting hood. When the latter is removed the current passing to the primary coil of the transformer is automatically stopped. The oscillator consists of a helical spiral with an inductance of approximately three microhenries. The resonator is another helical spiral. Its extremities and a point intermediate between them are connected to terminals seen on the top of the cabinet in front. By rotating the crank seen on the left of the terminals the resonator can be made to slide over the oscillator. In this way the current passing to the patient can be regulated. The handle seen on the right side of the terminals is the main switch of the machine. The maximum current consumption is about seven amperes on a 200-volt main. The frequency of the oscillation of the diathermy current is 2,500 kilocycles.

The " Thermo " Diathermy Machine.

(Cox-Cavendish Electrical Co.)

This machine is shown in Fig. 26. The condenser is made of zinc plates separated by glass. Its capacity is 0·003 microfarad. In the secondary coil of the transformer the voltage is stepped up to 5,000. The spark-gap is shown in the figure on the right side of the amperemeter. In construction it resembles that shown in Fig. 16. It contains a large copper disc and two others, smaller in size, which are placed under it, side by side. The sparks accompanying the discharge of the condenser pass across the two spaces between the large disc and the small underlying discs. The large disc can be raised or lowered by the ebonite rod seen on the top of the spark-gap container. In this way the width of the spaces can be varied. The air in the container is replaced by coal gas. The oscillator consists of a helical wire spiral. The resonator is a similar coil of larger diameter. By rotating the disc shown on the top of the cabinet on the left side in front, the oscillator can be made to slide over the resonator. In this way the current induced in the latter can be increased. The ends of the resonator are connected

to the two outermost of the three terminals seen on the top of the cabinet on the left side. The central terminal is connected to an intermediate coil of the resonator. By rotating the disc seen on the top of the cabinet in front of the spark-gap the current supplying the machine can be directed through a larger or smaller number of turns of the primary coil of the transformer. In this way the current of supply can be varied.

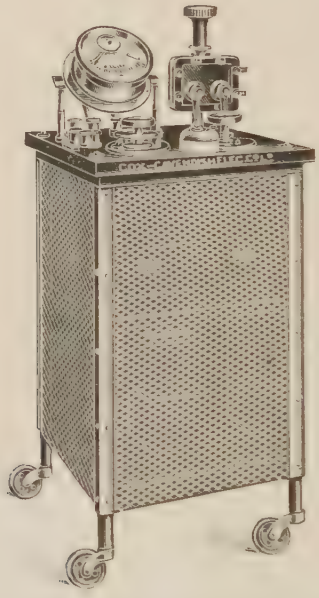

Fig. 26.—The " Thermo " diathermy machine.

The maximum current consumption on a 100-volt supply main is 7 amperes. The maximum voltage attained between the ends of the resonator is 15,000.

The " Taunton " Diathermy Machine.

(X-Rays, Limited.)

The constituent parts of this machine are assembled in two separate cabinets. This enables the operator to transport the machine from his house to the patient's home. Each cabinet is provided with handles by which it can be

carried from the house to a motor-car. The assembled machine is illustrated in Fig. 27. The lower cabinet contains the static transformer and the regulator for the current which is taken by the machine. The upper cabinet contains the condensers, the oscillator and resonator. On the top of

Fig. 27.—The " Taunton " diathermy machine.

this cabinet are mounted the spark-gap, amperemeter, main switch, three terminals and a coupling handle. The cabinet containing the transformer is mounted on rubber-tyred castors. The other cabinet is placed on top of it in the correct position. When this is done the necessary connections are automatically established.

The static transformer is provided with two windings

on the primary side which are adjusted for connection either to a low or a high voltage main A.C. supply. The main condenser is made of sheets of copper foil separated by mica, the whole being impregnated with insulating material. The spark-gap is of the " open " type. It resembles that shown in Fig. 12. It consists of silver discs, $2\frac{1}{4}$ in. in diameter, separated by mica washers. Two narrow air spaces are formed between the opposing surfaces of the discs and the sparks pass across them in series. The oscillator and resonator are flat spirals. By means of the disc seen on the cabinet in front of the amperemeter, the oscillator and resonator can be tightly or loosely coupled, so that the current to the patient can be varied. In circuit with the resonator are two small condensers. These are made of sheets of thick silver foil separated by glass. They are embedded in wax. The ends of the resonator are connected to the two outermost of three terminals. The middle terminal is connected to an intermediate point of the resonator.

The diathermy current received by the patient can be regulated either by the coupling disc or by a special controller worked by foot.

Another machine, the " Standard " Model, is similar to the " Taunton," but the parts are assembled in a single cabinet, so that it is not portable in the same sense as the machine just described. The " Standard " Model can be fitted with a spark-gap identical with that supplied with the " Taunton," or with another type which contains coal gas. In this gap the two spaces across which the sparks pass are bounded by three copper discs $\frac{3}{4}$ in. in diameter. One of these is placed between the others and is fixed. The other two are movable and can be rotated by means of screw handles so as to approach or move away from the central disc. In this way the spaces can be varied and the total width of the gaps narrowed or widened.

Both the " Taunton " and " Standard " are machines of medium size and give sufficient current both for surgical and medical purposes.

The Canny-Ryall Diathermy Machine.

(Watson and Sons.)

This machine was designed for the destruction of papillomata of the urinary bladder. In the hands of the author it yields current enough to destroy larger masses of tissue and give satisfactory results in surgical diathermy in other parts of the body. It can furnish also a high-frequency current of voltage high enough to operate the so-called vacuum electrodes.

Fig. 28.—" Canny-Ryall " diathermy machine.

The machine is shown in Fig. 28. It is readily portable. On the marble slab forming the cover of the case can be seen, in front (left side), four plug-openings. By one of these connection is made to a main A.C. supply of 100 or 120 volts. If the main supply is 200 to 240 volts (A.C.) the connection is made with another plug-opening. A third plug-opening is for connection to a rotary coverter if the main supply is D.C. The fourth plug-opening is for connection to a foot switch which may be used in place of the hand switch. On the right side can be seen the spark-gap. On the upper part of the slab can be seen a scale and

a disc at its centre. By rotating this disc a pointer moves over the scale. When the pointer moves to the left the diathermy current yielded by the machine is increased from zero to maximum. When it moves to the right the current for the vacuum electrode is similarly increased.

The machine contains a static transformer. In the secondary coil of the latter the voltage of the current is raised to about 2,000. The condenser has a capacity of 0·01 microfarad and is made of sheets of tinfoil separated by paper. The spark-gap is of the "open" type. The sparks pass between two metal discs which are separated by a mica washer. The oscillator is a helical wire spiral. There are two resonators. Each is a helical wire spiral of slightly larger diameter than the oscillator. By turning the disc seen in Fig 28 at the centre of the scale the oscillator can be moved into either resonator according to the current desired, whether for diathermy or for operating the vacuum electrode. When it lies completely within the resonator (tight coupling) the current in the latter attains its maximum.

The frequency of the diathermy current is 400,000 per second.

Diathermy Machines of German Make.

Machines designed expressly for the production of the diathermy current were first constructed by Siemens and Halske, of Berlin, after the suggestions of Dr. Franz Nagelschmidt. One of these was introduced into the Electrical Department of St. Bartholomew's Hospital in 1910 and used there for many years.

Most machines of German design employ the "open" type of spark-gap in which the sparks pass through air between broad copper discs. Others employ a spark-gap in which the air between the discs is replaced by methylated spirit vapour.

In the German machines it is customary to provide three terminals to derive current from the resonator for the patient's use. Two of these are connected to the ends of the resonator, and the third to an intermediate point of the coil. The maximum difference of potential is obtained between the

ends of the resonator. The patient is brought into connection with the terminals attached to the ends when the current has to traverse a long course in the body (*e.g.* from foot to foot) and overcome a high resistance. If a shorter course of lower resistance is provided for the current the

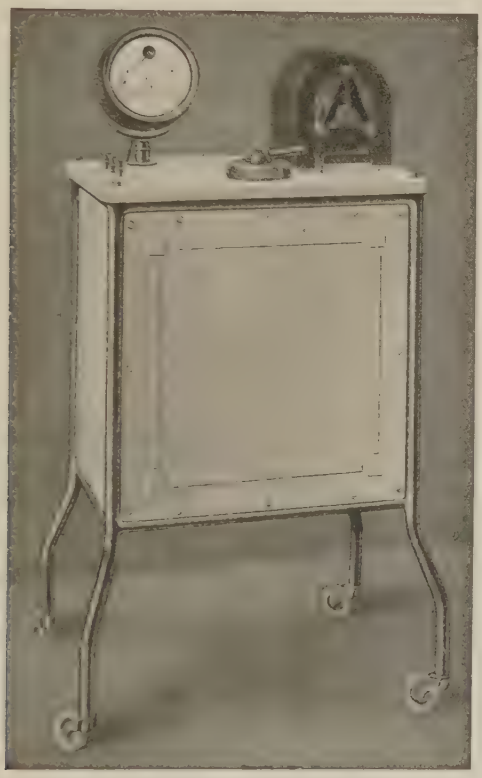

Fig. 29.—Diathermy machine by Siemens and Halske.

patient is brought into connection with one end of the resonator and the intermediate point. If a current at *high* voltage is passed along a circuit of *low* resistance some energy will be wasted and little heat will be developed in the tissues along the circuit. Little heat will likewise be developed if a current at *low* voltage is passed through a *high* resistance.

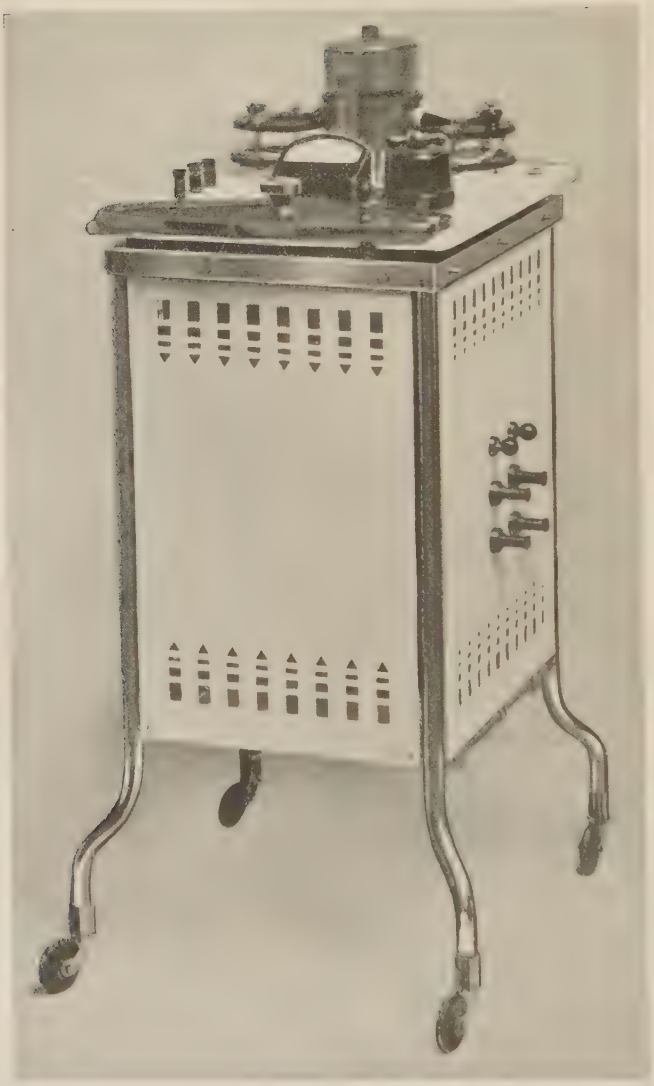

FIG. 30.—Diathermy machine by Reiniger, Gebbert and Schall.
(Neo-thermoflux-medium.)

The provision of three terminals renders it possible to apply diathermy to more than one region of the body at the same time. Three electrodes can be applied and connected to the three terminals respectively. Four or six electrodes can also be applied so as to include, say, two or three joints and treat them simultaneously. When more than two electrodes are applied it is necessary, however, to introduce variable resistances into the different circuits so that the different regions can be evenly heated. In some machines these resistances are included (*e.g.* those by Reiniger, Gebbert and Schall (see below). If they are not fitted a "current-distributor" (p. 79) may be employed.

Machine by Siemens and Halske.—This is shown in Fig. 29. The spark-gap is similar to that described on p. 35. The sparks pass between broad copper discs faced with silver and kept apart by mica washers. Overheating of the discs is prevented by means of hollow metal discs filled with water. These take the place of the metal fins fitted to the spark-gap shown in Fig. 11 at G.

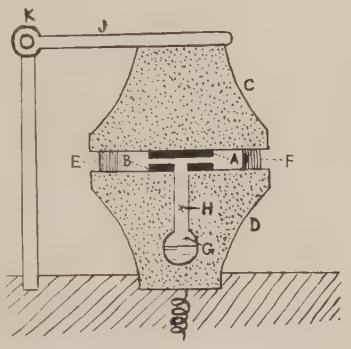

Fig. 31.—Spark-gap fitted to the "Neo-thermoflux" machine. (Vertical section: diagrammatic.)

Machine by Reiniger, Gebbert and Schall.—Three models are made: (1) the "Neo-Thermoflux" (medium size); (2) the "Neo-Thermoflux" (large size); (3) the "Microtherm"; this is of small size.

(*a*) The Neo-Thermoflux of medium size is illustrated in Fig. 30.

A special feature of this machine is the spark-gap. It is shown diagrammatically in section in Fig. 31. The space across which the sparks pass lies between two silver discs (A and B) which are placed horizontally. The discs are secured to metal blocks (C and D). The upper block is supported by the lower, but is prevented from making contact with it by means of the insulating ring seen in

section at E and F. By means of this ring the silver discs are maintained in close proximity without contact. In this way a gap 1 mm. wide is formed. The lower disc is perforated at its centre so as to communicate with the

Fig. 32.—Diathermy machine by Gaiffe-Gallot et Pilon.

channel H, which contains a wick. This wick leads methylated spirit from a couple of reservoirs. These can be seen in Fig. 30 on each side of the metal hood enclosing the spark-gap. The upper metal block C can be raised off the lower by a hinge movement at K. This is effected in the actual

machine by unfastening a locking lever and turning back the upper part of the hood. The discs can thus be quickly rendered accessible for cleaning.

Another feature of this machine is the presence of a so-called "load circuit." This is a second resonator, the circuit of which is completed by couple of lamps. When the oscillator is uncoupled from the first resonator (thereby producing no current in it) it is coupled to the second resonator and produces current in it. The lamps then glow brightly. The converse happens when the oscillator is moved away from the second towards the first resonator. The current diminishes in the former and the lamps glow less brightly and finally cease to emit light. At the same time the current in the first resonator increases progressively to its maximum. The current in this resonator is supplied to the patient.

The introduction of the load circuit prevents undue intake of current of supply when the machine is not giving its full output. The silver discs of the spark-gap are therefore spared and maintain an even surface for a long time.

(b) *Neo-Thermoflux of large size.*—This is similar in design to that described above, but gives double the output. It contains two spark-gaps. Two or three patients can be treated simultaneously.

(c) *The Microtherm.*—This also is similar in design to the other models of Neo-Thermoflux machine, but is small in size and suitable for surgical diathermy only.

Other German and Austrian firms construct diathermy machines of small, medium and large size. All generate the current on the same principle and are constructed on the same general plan. Some contain gaps in which the sparks pass through air; in others methylated spirit is used. Among these firms are Koch and Sterzel, Szieghart, Seifert, Agema (Germany) and Schulmeister (Vienna).

The machines by Siemens and Halske, and by Reiniger, Gebbert and Schall are used in England and can be obtained through the agency of the General Radiological and Surgical Co., London.

Diathermy Machines of French Design.

Gaiffe-Gallot et Pilon, of Paris, make a diathermy machine which presents certain distinctive features. It is shown in Fig. 32. The plan is shown in Fig. 33. ABC represents the combined oscillator and resonator. It is made of stiff copper ribbon. The portion from A to B is the oscillator and that from B to C is the resonator. There are two main condensers, D and E. One set of plates of E is connected to the end A of the oscillator. One set of plates of the other condenser D is connected to the other end B of the oscillator. The two terminals which are connected to the patient's electrodes are shown at (1) and (2). One of these is connected to the end A of the oscillator; the other terminal is connected to the end C of the resonator; B is a movable contact. By means of the disc seen on the front of the cabinet (Fig. 32) it can be made to slide along the coil either towards A (Fig. 33) or towards C. If moved towards A the length of the oscillator is diminished and that of the resonator increased. As it approaches A the current in the resonator diminishes, and finally sinks to zero, when B and A are in contact. On the other hand, when B is moved from A towards C the current in the resonator increases. It reaches its maximum when B is near C. Two small condensers, F and G, are inserted in series in the circuit containing the resonator.

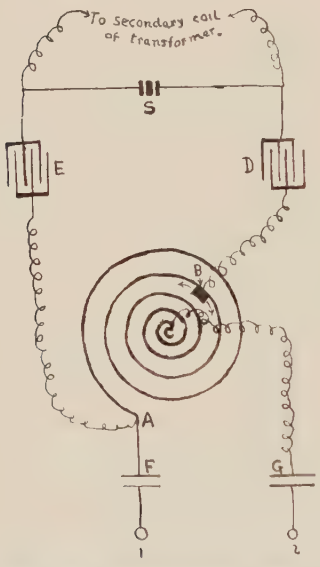

Fig. 33.—Explanatory plan of diathermy machine by Gaiffe-Gallot et Pilon.

The spark-gap is of the type introduced by Broca. It consists of an aluminium cylindrical chamber, the ends of which are closed by mica discs. Attached to the centre of

each disc is a thick screw, one end of which is in the interior of the chamber and the other end outside. The inner end carries a copper disc, the outer end a milled-edge button. A third copper disc is fixed in the interior of the chamber. The spaces across which the sparks pass lie between the third disc and those attached to the inner ends of the screws. By turning the latter the width of the spaces can be varied. The air in the interior of the chamber is replaced by coal gas.

Diathermy Machines of American Design.

The diathermy machines made by various firms in the United States of America differ markedly, in some respects, from those designed by European makers. Multiple spark-gaps of the "open" type seem to have been universally adopted. The sparks pass between narrow tungsten discs. In the smaller machines there are three or four pairs of discs. In the larger machines there are six, eight, ten or more pairs. The distance between each pair can be varied as desired or reduced to zero. The discs are mounted on the ends of metal blocks. Metal fins are attached to the latter in order to prevent overheating.

In the larger machines the main condensers are of the Leyden jar type; in the smaller models plate condensers are used.

For the purpose of regulating the current to the patient the method is quite different from that adopted in European machines. In the American machines the regulation is effected both by altering the strength of the current supplied to the machine and by varying the width and number of air spaces in the spark-gap. These methods of regulation are used in conjunction. If the operator desires to administer only a small diathermy current the spark-gap is narrowed; either by reducing the width of all the air spaces or by closing some altogether. At the same time the current taken by the machine is reduced to a small amount. If a stronger diathermy current is desired the incoming current is increased and the spark-gap is widened. The machines give their maximum output when the current supplied to them attains

the maximum value for which they are designed and the spark-gap is at its maximum width. If they are widened beyond a certain limit the sparks become very noisy and the patient may feel a " faradic " sensation.

The larger American machines are provided with Oudin or Tesla transformers whereby high-voltage currents are obtained for treatment by the high-frequency effluve and for those forms of surgical treatment known as " fulguration " and " electro-desiccation."

The latest machines are provided, in addition, with thermionic valves so that the so-called " cutting current " used in surgery can be obtained (see *Surgical Diathermy*, p. 244).

Diathermy Machines by H. G. Fischer.

Machines of small, medium and large size are made. By the courtesy of Mr. Fischer the writer was shown the construction and testing of the various models in the workshops and laboratories of the factory at Chicago. The machine illustrated in Fig. 34 is one of medium size. An explanatory plan is shown in Fig. 35. AB represents the primary coil of a static transformer. One of the cables from the main is connected to the end A. The other cable can be connected either to the end B or to any of the intermediate turns of the coil. The main condensers are represented at E and F, and the spark-gap at S. The coil GH represents the oscillator, and HL the resonator. The terminals (0), (1), (2), (3) and (4) are connected to various points of the oscillator and resonator.

The alternating current from the main passes along the primary coil of the transformer, either its entire length or as many turns as desired. By rotating the crank shown at the centre of the panel (Fig. 34) the number of turns included in the main supply circuit can be varied. In this way the voltage to which the current in the secondary coil of the transformer is raised can be regulated, as well as the voltage of the current supplied to the patient. The main condensers are charged from the current induced in the secondary coil. The high-frequency current accompanying their discharge

oscillates in the circuit containing the condensers, spark-gap and the coil GH (the oscillator). The current for the patient is taken from the end G of the oscillator by way of the terminal (0), and from another turn of the oscillator or

FIG. 34. Diathermy machine by H. G. Fischer, Chicago. (Smaller and larger models are made. The five terminals from which current is led to the patient (0 to 4, fig. 35) can be seen on the lower end of the panel. The crank at the centre regulates the current taken by the machine. The spark-gap is seen on the top of the cabinet, and the ammeter just below it.

resonator (M, H, K or L) by way of the terminals (1), (2), (3) or (4). If a low voltage current is required, as for diathermic coagulation or for treatment of a region of the body

offering low resistance, the cables from the patient are attached to the terminals (0) and (1). These derive a low-voltage current from the end G of the oscillator and from another point (M) a few turns away. The current derived from the terminals (0) and (2) is supplied at a medium voltage; that derived from (0) and (3) is supplied at a high voltage; that derived from (0) and (4) is supplied at a much higher voltage. The points of the oscillator and resonator to which these terminals are connected are fixed. The currents at medium and high voltage are used for treatment of regions of the body that present a medium and high resistance. The current derived from the extreme end L of the resonator is at a voltage high enough to give a brush discharge. When it is employed the patient is not, as a rule, connected to the terminal (0), the application being mono-polar.

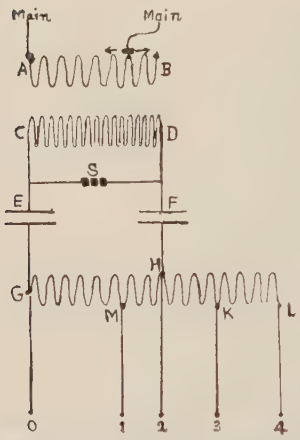

FIG. 35. Explanatory plan of machine shown in Fig. 34.

When a patient is to be subjected to diathermy the region of the body requiring treatment, whether of low, medium or high resistance, will decide the terminals to which the electrodes are connected. If the current is to be directed from hand to hand, or from foot to foot, the resistance will be high, and the electrodes should be connected to (0) and (3). If a single joint is to be treated the electrodes should be placed on opposite aspects and connected to (0) and (1). If a region of the trunk is to be treated the electrodes may be connected to (0) and (2). The strength of the current is regulated (1) by varying the number of turns of the primary coil of the transformer traversed by the main supply current, and (2) by varying the width of the spark-gap. The former gives even regulation within narrow limits, and the latter gives *abrupt* regulation in steps, but within broad limits.

In actual practice the procedure is as follows. After connecting the patient to the correct terminals, as stated

above, the crank shown in the centre of the panel (Fig. 34) is placed with its pointer at I.

The spark-gap is closed. This is effected by rotating the ebonite handle shown in Fig. 34 on the summit of the cabinet. The supply current is switched on. The spark-gap is opened and gradually widened to the maximum. If the amperemeter does not indicate the desired current for the patient the current from the main is switched off, the

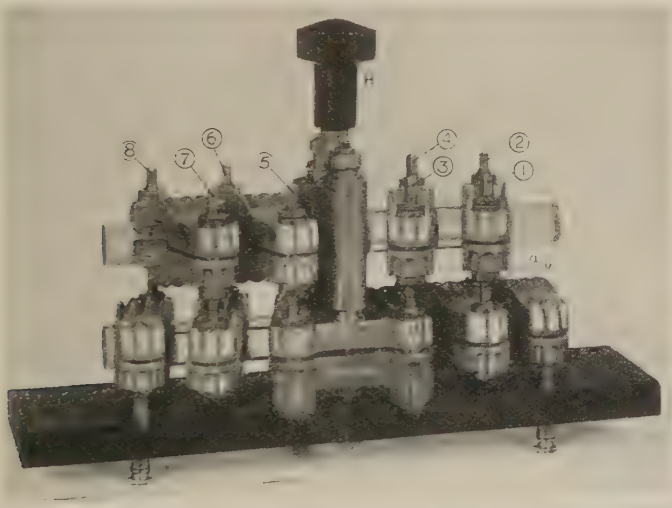

FIG. 36.—Spark-gap fitted to diathermy machine by H. G. Fischer. There are eight separate gaps. *a* and *b* are the tungsten-tipped discs bounding one of the gaps. By turning the master-key H the eight gaps can be closed, or their width varied, simultaneously. By turning any one of the ends (1) to (8) the width of the corresponding gap can be varied apart from the others.

spark-gap closed and the crank turned to (2). The main current is now switched on again and the spark-gap opened and its width increased. This process is repeated until the desired current is obtained for the patient.

After practice the operator will be able to set the crank approximately at the correct figure before commencing to treat different regions. He can then increase the current to the desired value by adjusting the width of the spark-gap.

The spark-gap is of the multiple type. There are eight separate gaps in series. Each is formed between tungsten discs. By rotating the handle shown in Fig. 34 on the top

of the cabinet the width of each gap can be varied simultaneously; all the gaps can be closed and all can be opened to the same width. On the other hand, one gap alone, or two or more, can be opened and the others left closed. The

FIG. 37.—Diathermy machine with three-electrode thermionic valve. (Nederlandsche Seintoestellen Fabriek, Amsterdam.)

first procedure is generally adopted. The closure of all the gaps save one and the regulation of the latter alone is practised when very fine adjustment of small currents is required, as, for example, in that form of surgical treatment known as electro-desiccation.

The spark-gap is shown separately in Fig. 36.

Diathermy Machine with Three-electrode Thermionic Valve.

A machine of this type is illustrated in Fig. 37. It is enclosed in a cabinet provided with swinging doors in front. When they are open, as shown in the figure, the current supplied to the machine is automatically interrupted. A plan of the constituent parts and their connections are shown in Fig. 38. The same numbers on this plan and in Fig. 37

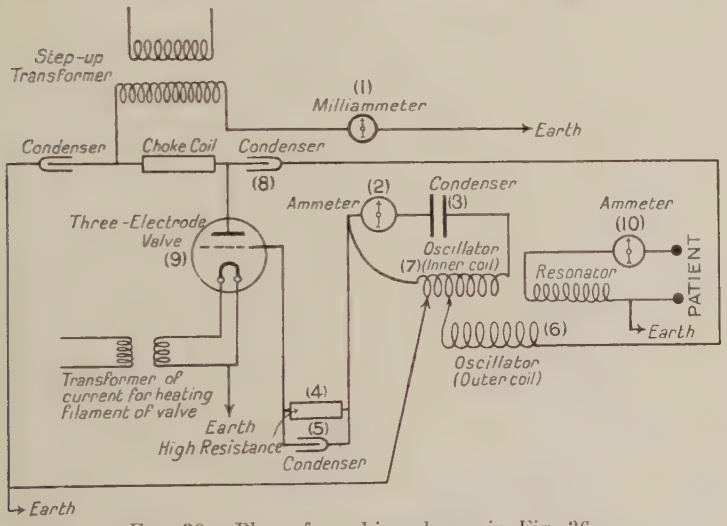

Fig. 38.—Plan of machine shown in Fig. 36.

correspond to the same parts. The three-electrode thermionic valve is shown at 9. The handle shown on the top of the cabinet (at H) is the coupling handle for regulating the current to the patient.

This machine was constructed by the Nederlandsche Seintoestellen Fabriek, of Amsterdam.

Notes on the Various Models of Diathermy Machine.

With respect to the various models of diathermy machine, the selection will depend in the first place on the branch of therapy in which the practitioner is mainly interested. If he desires to practise surgical diathermy alone, the small models are suitable and will furnish the current required.

They are portable by motor-car. Small rotary converters, also portable by car, are made for use with these models for operations in private houses in which the main supply is D.C.

The smallest models are suitable for minor surgical work only, such as the cauterisation of vesical papillomata and small masses of abnormal tissue.

For medical diathermy the models of medium size will suit the major number of practitioners. They supply ample current for surgical work as well. With regard to the various medium-size models which have been described, it may be said that there is little difference regarding the maximum strength of diathermy current obtainable from each, and all work satisfactorily in practice. As already shown, the main difference between machines of different make lies in the design of the spark-gap. A perfect spark-gap has yet to be designed. The type containing broad metal discs separated by mica washers (p. 37) works excellently, but cannot be regulated without dissembling the parts: the mica washers occasionally perforate. Those which contain coal gas are easily and quickly regulated, and, in the author's experience, are less likely to overheat during long-continued and heavy work, as in hospital practice. The type of spark-gap which contains methylated spirit requires little attention. Machines with this type do not give their full output of current until the metal discs become warm; when they are started and the discs are cold a minute or two must elapse before they become warm enough to enable the machines to yield their full output.

If coal gas is not available a machine can be selected in which the sparks pass through air or methylated spirit.

Some machines deliver current at a higher maximum voltage than others. If the current has to traverse a lengthy course in the body, such as from foot to foot, or from hand to hand, it will produce more heat if it is at a high voltage. On the other hand, if the current passes through a broad region presenting a low resistance such as the chest or abdomen, it will produce more heat if it is at a relatively low voltage. Machines which deliver current at a high maximum voltage are most suitable for use with a condenser couch.

The author prefers the multiple spark-gap of the " open " type in which the sparks pass through the atmosphere between tungsten discs.[1] If there is a sufficient number of divisions there will be no overheating. Tungsten corrodes much more slowly than copper or silver. In " closed " gaps which contain coal-gas there is an accumulation of soot and the need for frequent cleaning. In medical diathermy it is very advantageous if the voltage at which the current is delivered can be varied within wide limits. The reason for this has been stated above. The writer is of the opinion that the maximum voltage at which the current is supplied in most machines might with advantage be further increased. He is at present investigating the subject and it appears that there is less unevenness in the degree to which different tissues on the path of the current are heated when the latter is delivered at higher voltage.

It is possible, however, to apply all the forms of diathermy treatment which are described in the present volume with all the machines of medium size that have been described, although, as stated above, some are more suitable for condenser couch work than others.

Machines of large size have not yet come into general use. Some have been adopted for hospital work and the treatment of more than one patient at the same time.

At the present time only one machine has been constructed for use without a rotary converter when the main supply is *direct* current. This has been described on p. 49. It can be used for surgical and medical diathermy. It is unsuitable for work with the condenser couch. Its output is smaller than that of machines of medium size operated by the main *alternating* current. On the other hand, it

[1] Spark-gaps of the multiple type between tungsten discs seem to be gaining popularity in Europe. They are almost universally used in America. They require very little attention and it is likely that they will be much more generally used in the near future. In this country Schall and Son and the Medical Supply Association have recently constructed machines with this type of spark-gap. The writer has worked with a large diathermy machine fitted with a spark-gap of this kind (shown in Fig. 36) made by H. G. Fischer and has found it needed no attention during the time it has been in use. A minor disadvantage of the multiple type of spark-gap is the noise made during operation. This can be lessened by enclosing the part in a case.

takes a smaller current and can readily be conveyed by private motor-car to the patient's home.

Machines which contain a thermionic valve do not require the periodic attention that has to be devoted to the spark-gap. They work without emitting a sound. In these machines there is much less waste of energy in the transformation of the low-frequency supply current into the high-frequency outgoing current. On the other hand, the life of the thermionic valve is limited. After the expiration of, say, 1,000 working hours a new valve must be fitted. Thermionic valves are costly. Smaller valves are less expensive than larger forms, but £10 is an average price.

The machine shown in Fig. 37 has been at work in the author's clinic about ten hours each week for nearly three years and is still in excellent order.

The Machine in Operation.

Machines fitted with spark-gaps produce a finely-crackling hissing sound. This sound comes from the spark-gap and is due to the discharges of the condenser. The sparks present the appearance of a non-luminous blue film when the metal bounding the gap is hot. When the metal is cold the film is luminous.

The operator should learn to recognise the sound made by his machine when the spark-gap is in order. If the sound is muffled the spark-gap requires attention, particularly if the muffling persists after the metal bounding the gap becomes hot. The attention that should be given to the spark-gap is described below.

When a patient is under treatment the movement of the amperemeter needle will indicate whether the spark-gap needs attention. A sudden swing-back of the needle towards zero or its failure to remain stationary shows that the spark-gap requires cleaning. When the machine has been in operation for a long time, without rest, the metal bounding the gap is liable to overheat, especially if a large current has been used. If it becomes too hot the diathermy current will diminish and the amperemeter needle will gradually move back towards zero. The modern types of spark-gap

are more efficient in regard to absence of overheating than the original models.

Machines which contain spirit in the gap emit a spluttering noise when the gap is cold and yield little current until the metal becomes hot.

If two wires are connected to the terminals from which the diathermy current is taken, and their free ends brought near each other, a train of thick white sparks will pass across the gap in very rapid succession. In some machines they will pass when the ends are brought to an eighth of an inch from each other. In others they will bridge a longer gap.

Care of the Diathermy Machine.

The care of the diathermy machine is the care of the spark-gap. If this part does not receive periodic attention the machine will not give its full output.

The silver-faced copper discs of the spark-gaps in the machines by Dean, Siemens and Halske, etc. should be inspected every two or three weeks—if the machines are used daily. The silver surfaces tend to pit and become irregular after prolonged usage. When this happens they should be smoothed with emery paper. It is a good plan to place each pair of discs face to face, with a sheet of the finest emery paper in between, and rub each plate over the other. In this way a perfectly plane surface can be obtained. When the silver faces have been smoothed in this way the sparks crossing the gap acquire a yellowish hue and the machine does not give its maximum current for a few minutes. The non-luminous blue film gradually reappears and the current regains its full intensity. The silver loses its polish very quickly and assumes a dull grey colour; this is its normal appearance.

A thin grey deposit collects on the mica washers and should be wiped off occasionally with methylated spirit.

Perforation of a mica washer is recognised by a sudden increase of the customary sound heard when the machine is working normally. A small arc appears at the site of the perforation and the amperemeter needle falls back towards

zero. The current supplying the machine must be stopped and a new washer fitted.

Soot accumulates in the chambers in which the sparks pass through coal gas and, if it is not removed, will eventually fill them completely. It should be cleared away after the machine has been in operation for a total duration of twelve hours. If this is not done the current supplied by the machine will diminish and tend to vary from minute to minute. The copper discs are very slowly consumed, but can be replaced by new ones when necessary. Before this, however, the surfaces between which the sparks pass tend to become irregularly concave or convex. As soon as this irregularity is noticed the surfaces should be smoothed with a fine file. If the practitioner is unable to obtain a smooth symmetrical surface the discs should be handed to a mechanic.

In the machines in which methylated spirit is supplied to the spark-gap the silver discs require smoothing every two or three months.

Apart from the attention required by the spark-gap the machine should be kept free from dust. If the main condenser is immersed in oil the latter tends slowly to creep up the sides of its container, and form a film on the cover. The latter should be wiped from time to time to prevent undue accumulation of oil.

It is a good plan for the operator occasionally to test the output of his machine by passing the current through himself by way of cylindrical electrodes grasped in the hands. This should be done when the machine is new, and the reading of the amperemeter noted when the machine is adjusted to give its maximum output. When the wrists are of average size the needle should indicate a current of 0·5 to 0·8 ampere according to the machine used. These figures refer to machines of medium size. If the amperemeter indicates less than the current yielded when the machine is in perfect order the spark-gap should receive attention.

Note on the Amperemeter Readings.

It is important that the student should realise that the amperemeter readings afford no practical guide to the degree or amount of heat which the current generates in the body. The instrument only measures the current (or, more correctly, the heat-producing power of the current) passing through its resistance wire. It does not indicate how much heat the current generates in the body tissues. The amount depends not only on the strength of the current, but also on other factors, such as the size of the electrodes and the resistance (impedance) of the tissues. This subject will receive attention later when dosage is considered in the chapter on medical diathermy. Here it will be sufficient to say that the current which gives a relatively high amperemeter reading when passed through the body, say from hand to hand, does not necessarily produce more heat than the current from another machine directed along the same circuit and giving a relatively low amperemeter reading. A current which heats the amperemeter resistance wire most does not necessarily heat the tissues most. The converse also is true.

Accessory Apparatus.

Current Distributor.—This may be used when it is desired to subject two or more regions, or more than one patient, to diathermy at the same time. It consists of a set of variable resistance coils. These are helical wire spirals. A set of two, three or four are mounted on an insulating board. Their connections with the diathermy machine and the different patients or regions are shown diagrammatically in Fig. 39. 1, 2, 3, and 4 represent four coils of wire. A, B, C, and D represent four pairs of electrodes. The current from

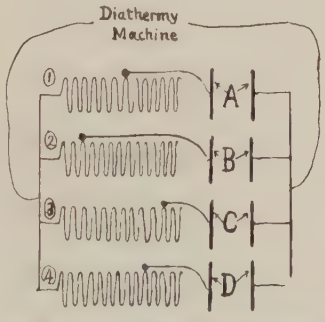

FIG. 39.—Current distributor.

the machine is distributed along four paths. A resistance is included in each, and the amount included can be adjusted by means of the sliders which can be moved along the coils. If one region of the body included between one pair of electrodes has a lower resistance than the others, a greater length of the wire coil should be introduced into the circuit. When the machine is in operation and the regions between each pair of electrodes are being unevenly heated, the necessary adjustments can be made; more resistance should be introduced into that circuit which contains the region which is becoming too hot, and *vice versa*.

When using a current distributor it must be remembered the current is being shared by more than one region or patient at the same time. It is therefore impossible to procure a high degree of diathermy in each unless the regions are small. If they are large or if two or more patients are to be treated simultaneously, a large diathermy machine should be used.

A current distributor is fitted to the Neo-Thermoflux machines of medium and large size (pp. 62–65).

The Bucky Alternator.—This is a device for securing a "cross fire" application of the diathermy current. Four electrodes are applied to a region, *e.g.* the knee. Two are placed on the anterior and posterior aspects and two on the lateral aspects. The current is directed in succession anterior-posteriorly and laterally. The change in direction is effected by means of an electric motor.

It is claimed that the interior of the region can be heated to a higher degree by the "cross fire" method than when the current is applied in one direction continuously for half the duration of a session and then for the remainder in the other direction.

Transformer for yielding a Brush Discharge.—Some diathermy machines are fitted with attachments whereby an accessory transformer can be attached and the so-called "high-frequency effluve" obtained. The transformer consists of two coils of wire, the primary and secondary. The primary coil consists of a few turns of thick wire; its ends are connected to two terminals, provided for the purpose, on the diathermy machine. The secondary coil contains a very

large number of turns of finer wire. It has a smaller diameter than the primary coil, and it is mounted so that it lies within the latter, the long axes of both coils being the same. When the diathermy current oscillates in the primary coil, another current of much higher voltage (but of proportionately reduced amperage) oscillates in the secondary coil. If the end of the secondary coil is connected to a suitable electrode a brush discharge can be obtained from the latter.

This transformer is known as the Tesla type. Some of the American machines are fitted with resonators of the Oudin type.

High-frequency Currents of sustained, unsustained, damped and undamped Oscillation.—The meaning of these expressions will be more clearly understood by reference to the graphs shown below.

In Fig. 40, A represents a high-frequency current in which the alternations (oscillations) are *undamped.* The amplitude of each oscillation is the same. If each oscillation or group of oscillations follows its predecessor without any interval of rest, the oscillation is said to be *sustained.* Groups of *damped* oscillations are shown at B. The amplitude of each oscillation is less than its predecessor and the oscillation ceases. But as soon as it ceases the next group of oscillations commences. The oscillation is *sustained* because there are no intervals of rest between each group. In each group, however, the oscillations are damped. In Fig. 40, C represents groups of damped oscillations with intervals of rest between the groups. The oscillation is damped and unsustained. The intervals of rest, however, are very brief. At D the oscillations are damped and unsustained, and the intervals of rest are longer.

The current represented at A will generate heat at the most rapid rate; that at B will generate heat at a less rapid rate because its intensity is changing periodically from maximum to zero. The current represented at C will generate heat at a slower rate because there are intervals of rest between successive groups of oscillations.

In order that the currents represented at A, B and C may generate the same quantities of heat they must flow

for different lengths of time. The current of sustained undamped oscillation generates heat at the most rapid rate,

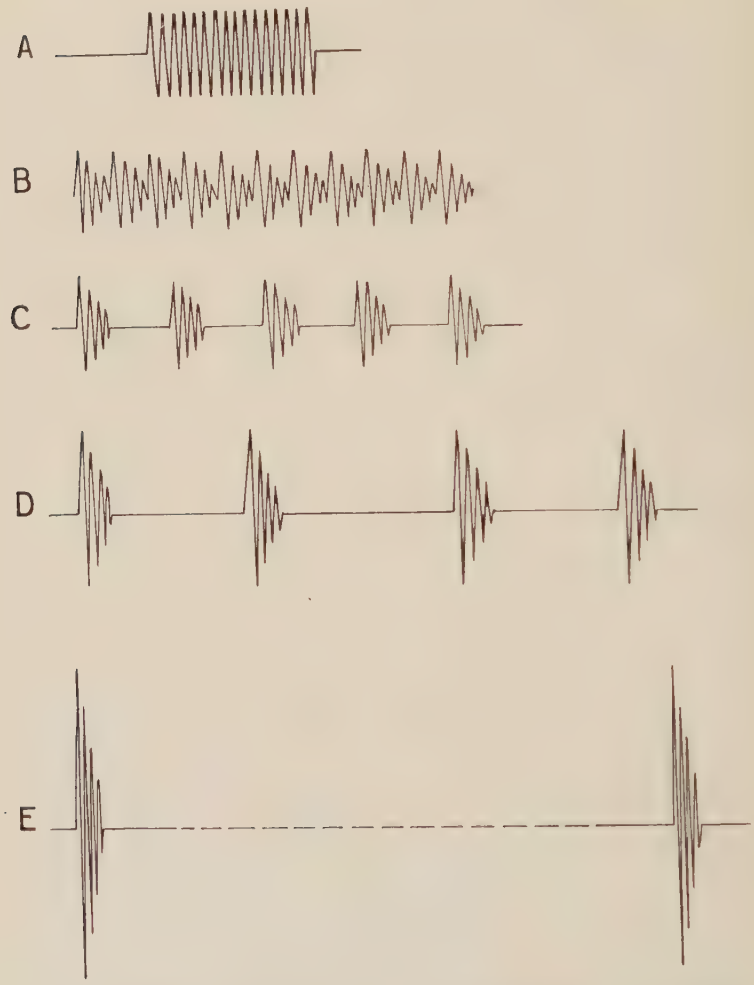

FIG. 40.—A. Group of sustained undamped oscillations. B. Sustained damped oscillations. C. Unsustained damped oscillations. D. Damped oscillations, more unsustained than in C. E. Damped oscillations, very unsustained. In E and D the voltage reaches a higher maximum than in C, B, or A.

and will produce a definite quantity in a shorter time than the current of sustained damped oscillation, and in a still

shorter time than the current of damped unsustained oscillation. If the intervals of rest between the groups of oscillation are unduly long, the heat which the current generates will be dissipated by convection and conduction as fast as it is produced. When this happens the region traversed by the current will not rise in temperature. The heat produced locally will be conveyed to other parts and the whole body will tend to rise in temperature. Even this general tendency may be neutralised by loss of heat by radiation from the exterior of the body. On the other hand, if heat is generated at the most rapid rate, as by the current of sustained undamped oscillation, it will quickly " accumulate " and the region traversed by the current will attain an increasingly high temperature.

Machines which contain a three-electrode valve generate currents of sustained undamped oscillation. The same is true of machines which generate them on the Poulsen arc system. The modern diathermy machines containing spark-gaps may sometimes generate current as represented at B in Fig. 40, but it is more likely that there are very short intervals of rest between successive groups of oscillations. They generate heat fast enough to produce degrees of diathermy high enough for therapeutic purposes.

The original d'Arsonval transformer generated heat at a very slow rate, and the heat was dissipated almost as fast as it was produced. The intervals of rest between successive groups of oscillations were, relatively, of very long duration (see Fig. 40, E).

If the current is transformed by means of an Oudin resonator or Tesla coil into another at much higher voltage its amperage is correspondingly *lowered* and it is unable to generate much heat within the body. It can, however, produce long sparks and brush discharges, and these have certain surgical and medical uses.

In some of the surgical uses of high-frequency currents the voltage and the degree to which the oscillations are sustained are matters of importance.

CHAPTER VII

THE PATH AND DISTRIBUTION OF THE DIATHERMY CURRENT IN VARIOUS CONDUCTORS

In this chapter it is shown that the diathermy current does not distribute itself like the constant current in different conductors. Experiments are described to show that it passes through the deep tissues of the living subject without being restricted to the superficial regions. The question of its distribution among tissues of different degrees of conductivity on its path is considered. The important bearing of the distribution of the current on the situation of the electrodes when diathermy is administered is shown.

The path and distribution of the constant current is determined solely by the *resistance* of the conductor. If the latter is homogeneous the current is uniformly distributed through the cross section of the conductor. When, however, the current oscillates with high frequency there are other factors, in addition to the resistance, which decide its distribution. These are the *capacity* of the conductor, the *self-induction* that takes place in the conductor, and the *frequency* of the oscillation. For these reasons the term *impedance* is used in place of *resistance* to express the opposition which a high-frequency current encounters in a conductor.

The capacity and amount of self-induction depend on the form of the conductor and its composition. If the conductor is made of metal, more self-induction can take place in it than is possible in solutions containing ions. The capacity of a metal conductor is very small in comparison with that of a mass of gelatin of the same size and shape containing ions to enable it to conduct the current. A conductor of the latter kind with metal plates attached to it so as to connect it to a source of high-frequency current constitutes a condenser with an imperfect dielectric; the gelatin has a higher resistance than the metal plates, and acts as the dielectric, while the plates form the armatures.

By reason of the facts above mentioned the distribution

of the high-frequency current in metal conductors is not the same as in objects which owe their conductivity to the presence of ions. As shown below, their distribution in metal conductors is quite different from that of the constant current, while in conductors containing ions the distribution of the two currents is not always the same.

Metal Conductors.—Whereas the constant current is evenly distributed through the cross section of a metal conductor, the diathermy current is restricted almost wholly to the surface. A very short distance below the surface there is no perceptible current. Thin-walled tubes, therefore, resist the diathermy current no more than solid metal rods of the same external diameter. This restriction of the current to the thin superficial layer of metal conductors is called the "skin effect." The use of this expression may cause confusion and lead to the assumption that the current is confined to the skin of living subjects without passing through deeper parts, when it is applied to the body. It will be shown later that this is not the case.

Conductors containing Ions.—When the diathermy current passes through a conductor containing ions it is not restricted to the surface; some passes through the deep parts as well. This has been shown by experiments such as the following: Gelatin or agar is dissolved in hot water containing a little salt. The solution is allowed to cool in a glass trough until it becomes semi-solid. The mass contains sodium and chlorine ions and is able to conduct electric currents. Plate electrodes are applied to the ends of the conductor and a diathermy current is passed through it. The path and distribution of the current can be approximately ascertained by inserting thermometers and noting the rise of temperature of different parts.

Some experiments of this kind were made by Prof. Lloyd Hopwood, Physicist to St. Bartholomew's Hospital. The conductors were made by dissolving gelatin in 0·5 per cent. salt solution, each litre of the latter containing $\frac{1}{2}$ lb. of gelatin. The solutions were allowed to set in glass moulds of various shapes. The current from a three-electrode valve diathermy machine was passed through the conductors by way of metal plate electrodes. The frequency of

alternation of the current was one million per second, and its strength was measured by means of a Weston radio frequency ammeter. Alcohol thermometers were placed in different parts of the gelatin. The current was passed through the

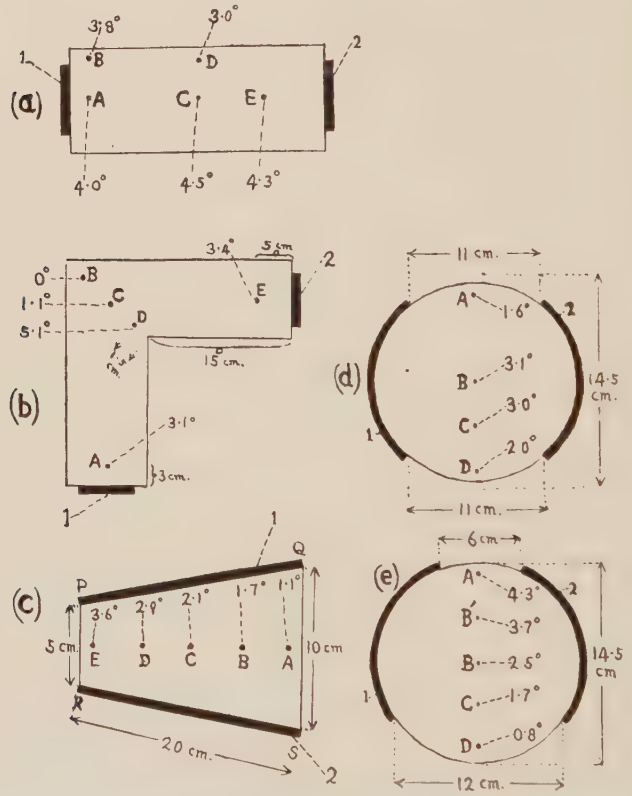

Fig. 41.—To illustrate the distribution of diathermy current in gelatin conductors of different forms (*a*, *b*, *c*, *d*, *e*), with electrodes (1 and 2) in different positions. A, B, C, D, and E indicate the position of thermometers, and the figures at the ends of the pointers show the rises of temperature registered by the thermometers at the ends of the experiments.

latter and the readings of the thermometers were noted at intervals.

In Fig. 41 the shapes of the conductors are indicated at *a*, *b*, *c*, *d* and *e*. The thermometers were placed at A, B, C, D and E. The final rises of temperature at these points are

shown by the figures at the ends of the pointers. The electrodes are indicated by 1 and 2.

The conductor shown at *a* is rectangular in section. The electrodes were placed at the opposite ends. It will be observed that the maximum rise of temperature was obtained at C, midway between the electrodes, the minimum rise being at D, one centimetre below the lateral surface. The temperatures obtained at other sites are indicated in the figure. There was but little difference between the temperatures indicated at the different sites. Some of the heat produced by the current was conducted to the surface of the gelatin and to the electrodes and lost by radiation and convection. At C the conditions were most favourable for the maintenance of the maximum temperature. At this spot the loss of heat by conduction was minimal. The experiment indicates that the distribution of current in those parts of the conductor included between the electrodes was uniform.

In the conductor indicated at *b* the maximum rise of temperature was recorded at D. There was no rise at B. At C the rise was only slight. The shortest path between the electrodes was in the vicinity of D. The distribution of the current, therefore, was uneven. Seeing that the path for the current between the electrodes was shorter through D than through C or B, a greater concentration of current through D would have been expected. But, judging by the temperature, the concentration at D was higher than that which the shortness of the path through this spot would have demanded. There was a disproportional concentration of the current along the short path.

This experiment was repeated under the same conditions, but a *low-frequency* current of the same strength was passed through the conductor for the same time. There was a slight rise of temperature at B, and the rise at D was lower than in the other experiment. The disproportional concentration at D did not occur.

In Fig. 41, *c*, the conductor is shown in longitudinal section. PQ and RS represent metal plate electrodes. PR and QS represent the glass walls of the receptacle holding the gelatin. Thermometers were placed at A, B, C, D and

E. At the end of the experiment the rises of temperature indicated by the thermometers are shown in the figure. The highest rise was obtained at E and the lowest at A. Here, again, the rise of temperature at E was more than in proportion to the shortness of the path through this spot.

In Fig. 41, *d*, the conductor, cylindrical in shape, is seen in cross section. The electrodes are curved and are placed on opposite sides in symmetrical relation to each other. Their corresponding edges were 11 cm. from each other, and their centres were 14·5 cm. apart. Thermometers were placed at A, B, C, and D. A and D were close to the periphery, B was 6 cm. from A, C was 3 cm. from B and the same distance from D. At the end of the experiment the rises of temperature were those indicated in the figure. The highest rises were at B and C. Those at A and D were lower. Although the electrodes were closer together at A and D, these spots were close to the surface and some heat was lost by convection and radiation.

In Fig. 41, *e*, the conductor and electrodes have the same dimensions as in *d*, but the electrodes were asymmetrically placed in relation to each other. Their edges were not equidistant but separated by a distance of 6 cm. where they were closest together, and by 12 cm. where they were farthest apart. Thermometers were placed at A, B, B′, C and D, each being 3 cm. from the adjoining one. The temperatures obtained are indicated in the figure. The maximum rise was obtained at A, where the corresponding edges of the electrodes were close together. The rise was maximum despite the fact that the situation of this spot was most favourable for loss of heat by convection and radiation.

In the above-described experiments strong currents were used and applied for short times only, in order to avoid, as far as possible, the errors that would arise from conduction of heat from spots at higher temperatures to others at lower degrees of heat. The observations show that there is no "skin effect" when the oscillatory current traverses objects of which the electrical conductivity depends on the presence of ions. They also show that when paths of different length lie between the electrodes the current shows a disproportional concentration in the shortest path. It will be shown

later that this fact has an important bearing on technique when diathermy is administered for therapeutic purposes. If the corresponding edges of the electrodes are unduly close there will be excessive concentration of the current in the tissues where the edges are closest together and burns will be produced.

With regard to the conductor shaped like the letter L (Fig. 41, *b*). it is interesting to note that the passage of the diathermy current along a flexed limb is followed by a rise of temperature which is much higher on the flexor than on the extensor aspect of the bent joint. Experiments which show this are described on pp. 102–104.

Tissue Conductors.—The conductivity of animal tissue is due to the presence of the ions in the fluids of the cells and intercellular spaces and those in the blood, lymph and secretions. Some tissues and fluids, such as muscle and blood, are richer in ions and better conductors than skin, bone, fat, etc., which are poor in ions. The body as a whole and different regions of it, therefore, are not homogeneous conductors. The same is true of each organ and tissue; the cell membranes are poorer in ions than the contained protoplasm and fluids in the intercellular spaces, and offer more resistance to the current. This being the case the cells can act as condensers, the cell membranes being the dielectrics and the protoplasm and intercellular fluid the armatures. It has already been mentioned that the conductivity of an object for high-frequency currents depends not only on the resistance but also on the capacity and inductance of the conductor. Since each cell can act as a capacity, a factor is introduced which further complicates the study of the distribution of these currents through the tissues.

There is, however, abundant evidence to prove that the diathermy current is not restricted to the skin or subcutaneous tissues in its passage between the electrodes placed on opposite aspects of the body. An early experiment was made by Maragliano to show this. Two metal plate electrodes were placed on the thorax of a dog, one on each side. In each pleural cavity a similar electrode was placed so as to lie in contact with the inner aspect of the thoracic wall under

the corresponding electrode on the outer aspect. A small electric lamp was placed in the interior of the thorax and connected to the plates in the pleural cavities. The external plates were connected to a high-frequency machine. When the latter was set in operation the lamp became incandescent.

This experiment showed that the current was not confined to the skin or subcutaneous tissues, but passed through the thoracic wall to the plates in the pleural cavities.

Furstenberg and Schemel placed electrodes on opposite aspects of the abdomen of a dog and connected them to a source of diathermy current. In the interior of the stomach a delicate temperature recorder was placed. As soon as the diathermy machine was set in operation the temperature in the stomach began to rise.

Cloetta and Waser showed [1] that the temperature of the brain of a dog could be raised by diathermy. A thermometer with its bulb in the lateral ventricle indicated a rise of one degree Centigrade after the current had been passed for ten minutes by way of electrodes placed on the exterior of the head.

The following experiment on the living subject shows that the current passes, in part at any rate, through deep-lying tissues midway between the electrodes.

The two palms, thoroughly moistened with saline, were pressed together, so that the thenar and hypothenar eminences made good contact over as large an area as possible. Electrodes were placed on the back of each hand. A thermometer was inserted, so that its bulb lay in the shallow depression between the thenar and hypothenar eminences. This depression was then obliterated by firm pressure together of the opposing palms. A current of 1·4 amp. was passed for six minutes. The thermometer showed a rise of 7° (95° to 102°).

Further proof of the penetration of the current is afforded by the coagulation of tissue for some distance under the electrode when strong currents are used for surgical purposes. A large fungating mass of growth, arising from the neck of a

[1] *Journal für Experimentale Pathologie und Pharmakologie*, June 25, 1914.

patient, was traversed by the current. A circular electrode $\frac{3}{4}$ in. in diameter was placed on it, and a thermometer was thrust in the growth so that its bulb lay about 1 in. below the electrode. Another electrode, a large metal plate, was placed on the chest. On increasing the current the thermometer was seen to rise. A temperature of 130° F. was quickly reached, and could have been exceeded. (The object in this case was to raise the growth to the supposed minimum lethal temperature for new growths of malignant type.)

These experiments show that the current is not confined to the skin or subcutaneous tissue. When the electrodes are placed on opposite aspects of a region of the body the current passes through the skin and the deep tissues as well.

With regard to the distribution of the current in the tissues between the electrodes it is difficult to obtain exact evidence in the living subject. Thermometers cannot give precise indication because the heat generated by the current is not confined to the path of the latter. It spreads by conduction, as in non-living conductors, to adjacent regions. To a greater or less extent it is conveyed by the blood and lymph streams to adjoining or distant regions. There is no doubt, however, that the distribution of the current in the region included between the electrodes depends largely on the position of the latter in relation to each other, and on the grouping of the different tissues between them.

If the electrodes are placed on opposite aspects of a region, parallel to and exactly opposite each other, the paths between their corresponding parts will be equidistant. If they are not parallel but in oblique relation to each other the current will be concentrated in the path where they are closest together (Fig. 42, *a*). The tissues along this path will become hotter in spite of redistribution of heat by conduction and convection.

If the electrodes are parallel but not directly opposite each other the current will attain a greater concentration in the path where they are closest together (Fig. 42, *b*).

If the electrodes are placed side by side, on the same aspect of the body, close together, but not touching, the current will be concentrated in the superficial tissues in the vicinity of the closely approximated edges (Fig. 42, *d*). This concen-

tration of current and heat in the region where the electrodes are closest together is called the "edge effect." It is also produced when curved electrodes are placed on opposite aspects of a limb and the edges of one are close to those of the other (Fig. 42, *f*).

If the electrodes completely encircle a limb (the so-called "cuff electrodes") and are close together the edge effect is again produced and the current will pass almost entirely

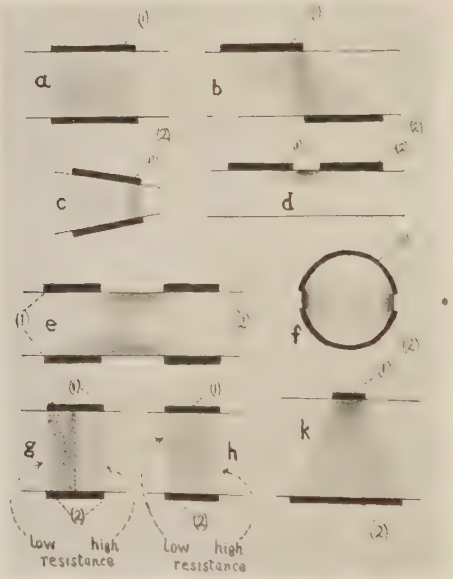

Fig. 42.—Diagrams to represent distribution of diathermy current in solid homogeneous electrolyte conductors with electrodes (1 and 2) in different relationship to each other and to the conductors.

along the superficial tissues (Fig. 42, *e*). Only when the cuff electrodes are placed at some distance from each other is it likely that the deep-lying tissues will receive much of the current, and only those that occupy the region midway between the electrodes.

If the electrodes are unequal in size and placed on opposite aspects of the body the concentration of the current will be least in the tissues immediately under the larger electrode and will progressively increase as the smaller electrode is approached (Fig. 42, *k*).

When tissues presenting different degrees of impedance lie between the electrodes the distribution of the current will show additional alterations *if they are grouped in parallel.* The current will attain a higher density in those which present a low degree of impedance and *vice versa* (Fig. 42, *g*). If they are grouped *in series* the current will show the same distribution in each, although, of course, those offering greater impedance will be heated to a higher degree (Fig. 42, *h*).

The following table shows the relative degrees of impedance of various tissues, that of 0·5 per cent. salt solution at 18° C. being taken as unity. The figures were determined by Wildermuth.

Adipose tissue	19·4
Brain	5·5—6·8
Lung	3·5—4·0
Liver	2·8—3·3
Skin	2·5—3·0
Muscle	1·2—1·5

Blood has an impedance which is a little greater than that of 0·5 per cent. salt solution.

The high impedance of adipose tissues and the low impedance of skin should be noted. In the case of the *constant* current the skin presents a higher resistance than any other tissue.

When the current is directed *longitudinally* along an extremity the tissues presenting different degrees of impedance are grouped *in parallel.* More current will pass along the blood and muscles than the skin, bone and fat. This is shown by the fact that the flexor region of the forearm, occupied mainly by muscle, will feel hotter and attain a higher temperature than the extensor region, which is occupied mainly by bone. Temperatures actually attained in an experiment are given on p. 102 (Experiment 3).

When, however, the current is directed *transversely* across the forearm by way of electrodes placed on opposite aspects the tissues of different impedance are grouped more *in series*, and the distribution of the current is less uneven. This is shown by the fact that the posterior aspect of the elbow

rises through a higher range of temperature than the anterior when the current is directed antero-posteriorly through the forearm in the region of the joint (Experiment 14, p. 107). The posterior region of the elbow is occupied mostly by bone, which has a higher impedance than the soft tissues of the anticubital fossa.

When the current is directed across the trunk the conditions are different from those present in a limb. If the electrodes are applied, say, to the anterior and posterior walls of the abdomen there are, in addition to the straight direct paths between them, others in outlying regions. It is likely that the major portion of the current passes along the straight paths. If a large portion passed along the outlying regions the concentration (density) of the current would be lowered considerably and the heat produced would be greatly reduced. It will be shown later (Experiment 10, p. 105) that the passage of the current across the abdomen is followed by a rise of the oral temperature. Heat is generated in the tissues traversed by the current and carried to other regions by the blood.

It has already been stated that the current, in its passage along metal conductors, is restricted almost entirely to the surface of the latter. The question arises of the distribution of the current in its passage between metal electrodes and the body. When the diathermy current is passed through the body by way of metal plate electrodes placed in contact with the skin, more current passes through the skin from the edges than from the central region. When surgical diathermy is performed and the current passed through the tissues by way of a narrow disc electrode it will be noted that coagulation begins under the edge of the disc. The current does not, however, pass wholly from the edge although it attains its highest density there. When larger electrodes and smaller currents are used, as in medical diathermy, the erythema that develops in the skin is most marked under the peripheral portions of the electrode but is not restricted to the edges. It fades away as the centre is approached.

During some applications of treatment thermometers were placed between the electrodes and the skin in order to ascertain the temperatures reached at the edges and centre. Electrodes measuring 4 inches by 4 inches were placed on

the abdomen and back, and a current of 2·4 amperes was passed for fifteen minutes. A temperature of 105° F. was obtained at the edge and 103·6° F. at the centre. These were the average figures.

The Path and Distribution of the Diathermy Current in and around the Cells.—It has already been mentioned that each cell with the extracellular fluid can act as a minute condenser with an imperfect dielectric. The horny layer of the skin can also act as a dielectric, especially when it is dry. A metal plate electrode placed on the skin acts as one of the armatures of a condenser, and the soft tissues under the horny layer constitute the other armature. If a metal plate is placed, say, on the back and another on the abdomen, and both are connected to a source of diathermy current, the charge on each plate will induce another of opposite sign in the soft tissues immediately under the epidermis. At each moment when the charges on the metal plates change their sign, the induced charges neutralise each other and a current will pass between the parts occupied by the induced charges. This current will oscillate with high frequency because the charges on the metal plates change their sign with the same frequency. The horny layer of the skin, however, is not an insulator although its resistance is high. It is also perforated by channels for the exit of the secretion of the sebaceous and sweat glands. When these channels contain secretion the current can pass along them without any intervening dielectric. It thus has two methods of reaching the tissues under the horny layer.

The cells of the stratum germinativum and those of other tissues can also act as imperfect condensers. The cell membrane, which is partially permeable, acts as a leaky dielectric and the protoplasm and extracellular fluid constitute the armatures. The current can pass along the extracellular fluid and can also induce charges on opposite sides of the cell membrane and cause currents to oscillate with high frequency inside the cell. This subject has been investigated by Prof. Philippson, whose experiments indicate that oscillatory currents of very high frequency are distributed more in proportion through the cells, wheras those of less high frequency of oscillation pass more in proportion in the intercellular spaces.

Resistance of the Body to the Diathermy Current.—The body presents a lower resistance to alternating than to constant currents, and if the frequency of the alternation is high the resistance is considerably reduced. Dowse and Iredell [1] showed that the resistance from hand to hand (cylindrical electrodes were held in the hands) varied between 450 and 650 ohms for the diathermy current. From deltoid to deltoid the resistance was 45 ohms. For the constant current the resistance from hand to hand (the hands immersed in saline) was found by Weiss to vary between 1,300 and 1,500 ohms.

[1] *Archives of Radiology and Electrotherapy*, July, 1920.

Philippson [1] experimented with portions of the bloodless liver of a rabbit and found a resistance of 1,950 ohms for a current alternating with a frequency of 500 per second. With a frequency of 50,000 the resistance was 1,025 ohms. With a frequency of 5,000,000 the resistance was as low as 245 ohms.

Practical Conclusions in Relation to Technique.—From what has been said it is evident that the position of the electrodes in relation to each other and to the organ or region requiring treatment is very important. This subject will be considered in full when instructions are given for the application of diathermy (p. 123), but here it may be mentioned that electrodes which are applied to the skin should be placed *on opposite aspects* of the region requiring treatment or the region containing the organ which is to receive diathermy. This is especially necessary when portions of the limbs, such as the joints, are to be treated.

The electrodes should, as near as possible, be parallel. If they are placed obliquely in relation to each other the current will be unduly concentrated in the parts where they are closest to each other. If they are curved and their corresponding edges are close together the so-called "edge effect" will occur; excessive concentration of current will occur in the tissues separating the closely approximated edges, and burns may occur even though the tissues elsewhere are scarcely warmed.

[1] Académie Royale de Belgique: *Bulletins de la Classe des sciences*; Séance du 4 Juin, 1921.

CHAPTER VIII

THE DEGREE AND DISTRIBUTION OF HEAT PRODUCED BY THE DIATHERMY CURRENT

In this chapter are recorded a number of experimental observations which show the degree to which the diathermy current can heat different regions of the body. It is shown that other factors in addition to the strength of the current have an important influence, not only on the degree, but also on the distribution of the heat.

The temperature to which an organ or region can be raised by the diathermy current depends on many factors. With machines of the type made at the present time it is possible to heat some regions to the maximum degree that can be tolerated, or even higher; other parts cannot be heated more than a trifling amount even when the machine is yielding its full output. The temperature which can be attained depends on many factors. These are (1) the strength of the current, (2) the duration of flow of the current, (3) the area of contact between the electrodes and the body, (4) the cross sectional area of the part traversed by the current, (5) the resistance of the tissues on the path of the current, (6) the blood supply of the tissues traversed by the current. To these factors must be added (7) the physiological response of the tissues when their temperature is raised.

(1) *Strength of the Current.*—The dependence of the temperature on the strength of the current is obvious.

(2) *Duration of Flow of the Current.*—The maximum degree of heat which the current can produce in any one region is not attained at once. If the region is small in bulk, *e.g.* the wrist, the maximum temperature is soon attained. A longer time is occupied in heating a larger region such as the thigh. To raise the temperature of the whole body by two or three degrees a much longer time must be occupied.

(3) *The Area of Contact between Electrodes and Body.*—If the current is directed through the body by way of plate

electrodes which are unequal in size, its concentration or *density* will be greater in the region under the small electrode than in the parts under the large electrode. The skin or mucous membrane under the small electrode will feel warmer and attain a higher temperature. If one of the electrodes is sufficiently small in area, say a square inch or less, the heat attained can be increased to a degree high enough to coagulate the tissues for a short distance underneath it. When the diathermy current is used for the purpose of destroying abnormal tissue (surgical diathermy), one of the electrodes makes a very small area of contact with the part which is to be destroyed.

(4) *Cross-sectional Area of Part traversed by Current.*—When the current is directed along a limb the cross-sectional area of its path is smaller than when the abdomen or thorax is included between the electrodes. The same current will heat a limb to a higher temperature than the abdomen or thorax, and the upper limb to a higher degree than the lower. The wrist, being smaller in cross section, will be heated more than the rest of the upper limb; for the same reason the ankle will attain a higher temperature than the leg or thigh.

(5) *The Resistance (Impedance) of the Tissues.*—The degree to which a region or tissue can be heated depends also on the amount of impedance offered to the current. Adipose tissue offers the highest degree of impedance, and blood serum the lowest. The relative degrees of impedance presented by various tissues is stated on p. 93. When tissues of different impedance constitute the path of the current the relative degree to which they are heated depends on their grouping in relation to the path of the current, whether in *series* or in *parallel*. When bone and muscle lie in parallel on the path of the current the latter will be heated to a higher degree than the former, in spite of the higher impedance of bone. If the current is directed, say, along the forearm, the extensor region, occupied, as it is, more by bone than by muscle, will become less hot than the flexor region. Some experiments which show the temperatures that can be attained will be described later.

(6) *The Blood Supply of the Tissues.*—The temperature which can be produced locally depends largely on the blood

supply of the part. The tendency of the blood is to convey heat away from the regions traversed by the current. If a large quantity of blood passes through the region the temperature of the latter will rise but slowly and it will not attain a high degree. This is the case when the abdominal and thoracic organs are traversed by the current. The reverse is the case in regions containing less vascular tissues such as muscle and bone.

The reasons why the circulation tends to inhibit a local rise of temperature are the following. Blood is continuously streaming through the region subjected to diathermy and is exposed to the heating action of the current for a far briefer period than the solid tissues. The temperature of the latter, therefore, rises first. But as soon as this happens the heat tends to pass, by conduction, from the tissues to the blood. The tissues, therefore, cannot attain the temperature which they would reach if no fluid passed through them, and the tendency of the current to heat them is opposed by that of the blood to reduce their temperature to its normal value.

If the direction of the blood flow is *across* rather than *along* the path of the current from one electrode to the other, more blood will pass through the heated region per unit of time and more heat will be carried away. Thus if the current is directed across a part of the chest or abdomen, more blood will pass across its path than would be the case if the current were directed along a limb. The abdominal and thoracic organs, therefore, will not attain as high a temperature as the tissues of the extremities.

It is evident, then, that the conditions in the trunk are all unfavourable to the production of high temperatures; the path of the current has a low resistance, there are outlying paths in addition to those directly included between the electrodes (and in consequence a lowering of the current density occurs) and a large amount of blood passing across the path of the current. On the other hand, the conditions are favourable when the current is directed along an extremity, especially the upper limb.

(7) *The Physiological Response of the Tissues.*—When an organ or region is heated its circulation is accelerated and more blood passes through. More heat, therefore, is carried

away. It must be remembered, also, that the heating of the skin under the electrodes causes a rise of temperature of the sensory nerve endings. The blood supply of the underlying parts may thereby be altered by reflex action. When Furstenberg and Schemel experimented on the dog and measured the temperature in the stomach when passing diathermy currents through the abdomen, they found that a current of 0·3 ampere caused a rise of temperature of 0·3° C. in the stomach, whereas a current of 2·0 amperes produced a rise of only 0·1° C. These results were repeatedly confirmed. The apparent paradox is explained rationally by assuming that the more intense heating of the cutaneous sensory nerve endings by the stronger current caused a reflex vaso-dilatation of the gastric vessels, a passage of a larger quantity of blood through the stomach walls and the convection away of a larger amount of heat. When the circulation was stopped by killing the animal it was found that stronger currents produced higher temperatures in the stomach.

This experiment has an important bearing on dosage in treatment. It shows that the strongest currents do not necessarily produce the highest degrees of diathermy. Those who are experienced in diathermo-therapy know that the strong currents do not always produce the best results.

The Distribution of the Heat generated locally by the Diathermy Current.—The heat which is taken by the blood from regions locally heated by the diathermy current is distributed in the general circulation. The temperature of the blood as a whole and that of other parts of the body tend to rise. When diathermy is applied to certain regions the circumstances are more favourable for producing a general rise of temperature. When the current is directed along an extremity the blood is confined to the path of the current and cannot pass out of it except at the end where it entered. It has, therefore, a comparatively long sojourn in the hot region and is heated more than would be possible if it passed *across* the path of the current, entering at one side and leaving at the other. Some of the blood which enters a limb at its proximal extremity has to pass through to the distal end, and this portion stays for the longest time in the heated territory. Since the upper limb is narrower in cross

section than the lower it has a higher resistance and can be heated to a higher temperature. The maximum general temperature can therefore be produced by passing the current along the upper extremities.

It is likely that the blood during its passage along an extremity is heated also *by the current itself*, as well as by conduction from the heated tissues. Its relatively long stay in the path of the current renders this possible.

The conditions attending the passage of the current across the abdomen or chest are unfavourable for a *general* as well as for a *local* rise of temperature. Little heat is generated in these regions and there is little heat for distribution elsewhere.

Some experiments which were made on a normal subject in order to ascertain the temperatures which could be obtained, locally and generally, when the diathermy current was passed through different regions are described below.

Experiment 1.—A current of 0·4 ampere was passed for twenty minutes. A cylindrical metal electrode was grasped in each hand. The subject of this experiment was seated, and the elbows and knees were semi-flexed. The heat was insufficient to cause discomfort.

The following rises of temperature were noted in different regions :

Front of wrist .	6° (from 94 to 100).
Front of elbow .	4° (from 95 to 99).
Axilla . . .	2·4° (from 98·8 to 101·2).
Mouth . . .	2·6° (from 97·6 to 100·2).
Groin . . .	1·2° (from 98·8 to 100).
Popliteal space .	3° (from 98 to 101).

Between first and second toes no rise was noted.

In this experiment the maximum rise of temperature was obtained in the wrist because the upper extremity has the smallest cross-sectional area in this region. The current attains the greatest density here. The cross-sectional area is larger in the region of the elbow and upper arm, and lower temperatures are attained in these parts. The rise of temperature of the mouth, groin and popliteal space was due to convection of heat from the upper limbs by the blood according to the principle already explained. It could not conceivably be explained by assuming that the current passed through these regions. Had it done so its lines of flow would have diverged greatly, its density correspondingly reduced and its heating power reduced almost to zero.

Experiment 2.—A current of 0·5 ampere was passed from hand to hand. The following rises of temperature were recorded in the elbow after the current had passed for ten minutes. The elbow was maintained in a position of full extension :—

Front of elbow	6·5° (from 93·5 to 100).
Back of elbow (by side of olecranon) .	5° (from 90 to 95).

In this experiment the current had to be interrupted after ten minutes, because the heat became intolerable in the wrists and the hold on the electrode could not be maintained. In the next experiment a current of 0·65 ampere was passed from hand to hand. After four minutes it had to be switched off. The following rises of temperature were recorded :

Experiment 3.	Front of wrist.	Back of wrist.
After 2 minutes...12°	(from 91 to 103).... 9°	(from 86 to 95).
After 3 minutes...16°	(from 91 to 107)....13°	(from 86 to 99).
After 4 minutes...20°	(from 91 to 111)....16°	(from 86 to 102).

These experiments show the inequality of the temperatures reached in regions where tissues of different impedance are grouped in parallel along the path of the current. The posterior (extensor) region of the wrist and elbow is occupied mainly by cartilage and bone. These tissues offer a higher impedance to the current than the vessels, tendons, etc. which occupy the anterior (flexor) region. The major portion of the current, therefore, travels along the latter region.

Experiment 4.—Current of 0·5 ampere passed for ten minutes from hand to hand, elbows *flexed to a right angle*. The following rises of temperature were noted :

Front of elbow	9·2° (from 93 to 102·2).
Back of elbow (by side of olecranon) .	3·4° (from 88 to 91·4).

This considerably greater rise of temperature on the front of the elbow when flexed is probably due to the fact that the path for the current is shorter along the flexor region, and so has a lower resistance. Also, as pointed out above, less resistant tissues lie in the flexor region.

The lowering of the resistance of the arm by flexing it can be easily demonstrated by passing the current along the *extended* limb, reading the amperemeter, and then bending the elbow. The amperemeter needle will then be seen to move forward and indicate that more current is passing.

When an electrode is placed on the palm, and the wrist flexed to a right angle, the major portion of the current will flow along the anterior region of the wrist, which, consequently, will be heated to a higher temperature than the posterior region. Along the anterior region are the shorter path and the less resistant tissues. If, on the contrary, the electrode is placed on the back of the hand and the wrist dorsiflexed as far as possible, the shorter path for the current will be along more resistant tissues, and there will be less difference between the temperatures attained on the posterior and anterior surfaces of the wrist.

Experiment 5. Electrode on *palm*. *Palmar-flexion* of wrist. Current passed for ten minutes. The following rises of temperature were noted :

Anterior aspect of wrist .	16° (from 89 to 105).
Posterior aspect of wrist .	6° (from 89 to 95).

This experiment, like No. 4, shows a much greater rise of temperature on the anterior aspect of the wrist, the path here being shorter and occupied by less resistant tissues. On the posterior aspect the path is longer and is occupied by more resistant tissues, and a much lower temperature is attained. As in the preceding experiment, the tissues of different resistance are grouped in parallel along the path of the current.

Experiment 6.—Electrode on *back* of hand. *Dorsi-flexion* of wrist. Current passed for ten minutes. The following rises were noted :

Anterior aspect of wrist . .	12° (from 93 to 105).
Posterior aspect of wrist . .	12° (from 92 to 104).

In this experiment the same rise of temperature was obtained on both aspects of the wrist because the posterior region, though occupied by more resistant tissues, provides a *shorter* path than the anterior.

Experiment 7.—Same subject as in Experiment 1. Sitting position with knees semi-flexed. A current of 0·7 ampere was passed from sole to sole, along the lower limbs, across the trunk, for twenty minutes. The following rises of temperature were noted :

Front of ankle . .	10° (from 94 to 104).
Popliteal space . .	18·5° (from 85 to 103·5).
Groin . . .	1° (from 99 to 100).
Mouth . . .	1° (from 98·2 to 99·2).

In this experiment the maximum temperature was obtained in the ankle, this region being narrower in cross-sectional area than other parts of the limb. The popliteal space reached a temperature nearly as high and it rose through a greater range. The probable explanation is the fact that in the region of the knee there is a much larger proportion of bone than soft tissue. In addition the limb was flexed at the knee and the popliteal space provided a shorter path for the current and one of lower resistance than that through the bone.

It will be noted, in this experiment, as in No. 1, that there was a rise of the oral temperature but to a less high degree. The lower limbs are broader conductors and less resistant than the upper extremities. Although higher temperatures were obtained in the ankle and popliteal space, the high degrees of pyrexia in these regions were localised and the blood quickly passed through them into broad parts, *viz.* the leg and thigh, where less heat can be generated. The subject felt less general heat during this experiment than on the occasion when the current was passed along the upper limbs. In both experiments the current was adjusted so that the heat could be tolerated in the narrowest parts without discomfort.

Experiment 8.—Knee *flexed* to right angle. Current directed from calf to calf. The following rises of temperature were noted :

Front of knee... 2° after 5 minutes, 3° after 10 minutes.
(91 to 93). (91 to 94).
Back of knee ... 9° after 5 minutes, 11° after 10 minutes.
(94 to 103). (94 to 105).

Experiment 9. – Knee *extended*. The following rises were noted :
Front of knee... 6° after 5 minutes, 10° after 10 minutes.
(91 to 97). (91 to 101).
Back of knee ... 7° after 5 minutes, 14° after 10 minutes.
(93 to 100). (93 to 107).

In these experiments a higher temperature was obtained on the flexor aspect of the knee than on the extensor, but the difference was less when the joint was extended. Similar observations were made in Experiments 2, 3 and 4, and the same explanation holds good for all.

When the soles rest on the electrodes and the current is passed along the lower limbs, the toes and front portion of

the feet do not feel any warmth, even though the ankles become very hot. The difference is very apparent to the touch. If the current is passed from sole to sole of a subject whose feet are cyanosed, a good ocular demonstration is obtained of the distribution of the heat. The toes and anterior portions of the feet retain their livid appearance, while the ankles and the parts of the feet immediately below gradually acquire a red hue.

When the diathermy current is directed across the trunk, the subject feels heat in the skin where covered by the electrodes. The general sensation of warmth, which was felt gradually to pervade the whole body when the current was directed along the limbs, is not perceived unless the current flows for much longer than twenty minutes.

Experiment 10.—Circular metal plate electrodes, 3 in. in diameter, were placed on the trunk, one on the abdominal wall below the umbilicus, the other on the lower lumbar region. A current of 0·8 ampere was passed for twenty minutes. The following rises of temperature were noted :

Skin under abdominal electrode	4° (from 95 to 99).
Skin under lumbar electrode .	9° (from 92 to 101).
Mouth	0·4° (from 99·6 to 100).
Axilla	0·6° (from 99·2 to 99·8).
Popliteal space	No rise.

In this experiment the conditions are, as already stated unsuitable for producing a high rise of the general temperature of the body. The figures obtained prove that this is the case. The only parts in which there was a fairly high rise of temperature were those in contact with the electrodes. The skin and fat have a higher resistance than the vascular abdominal organs and less blood passes through them. It is therefore unlikely that the temperature of the interior of the abdomen rises more than a slight amount. Some heat, nevertheless, is produced, because the oral and axillary temperatures rose slightly. This heat was doubtless produced along the path of the current in the abdomen and removed, by convection, by the blood stream. It seems unlikely that it was carried from the skin in contact with the electrodes because the area of contact was small. The electrodes, too, were applied with pressure sufficient to obliterate the subcutaneous capillaries.

In order to ascertain the temperature to which the interior of the abdomen or pelvis could be raised the following experiments were made :

Experiment 11.—A thermometer was placed with its bulb in the posterior fornix vaginæ of a patient, and electrodes were placed on the pubes and lower hypogastric and gluteal regions. After thirty minutes the following rises of temperature were noted :

Posterior fornix	0·4°	(99·2 to 99·6).
Mouth	0·4°	(98·4 to 98·8).

In this experiment the temperature of the interior of the pelvis rose, but no more than the oral temperature. It may be concluded, therefore, that the continuous passage of an abundant blood supply through the pelvic organs carried away the heat as fast as it was generated. In this way the temperature of the whole blood rose and, with it, the temperature of the pelvic organs. The blood is a heat-distributor. It does not allow heat to "accumulate" in regions which are highly vascular, and although their temperature may increase, the rise is not only local but also general.

If this conclusion is correct it follows that the passage of the current along the limbs and the heating of the blood should cause a rise of temperature in the interior of the pelvis. This is actually the case. A current of one ampere was passed for twenty minutes along the upper extremities. The temperature of the posterior fornix rose 0·4° (from 99·2 to 99·6) and that of the mouth 0·4° (from 98·8 to 99·2).

It might be thought, from the results of this experiment, that it would be as effective to direct the current along the limbs as through the pelvis when it is desired to heat the pelvic organs. This, however, is not probable. When the limbs are subjected to diathermy the pelvic organs are heated by convection. It is unlikely that the pelvic tissues are as thoroughly heated by way of the blood stream as by the current itself. The current passes *through* the tissues and *through* the cells irrespective of histological structure. Blood, on the other hand, passes *between* the cells or between groups of cells. By the current *all* the cells are heated. By the blood the cells in contact with the capillaries are heated;

the spread of heat to cells further away must be by conduction and, in consequence, slow. The current can heat a group of cells simultaneously from capillary to capillary. The heat in the cells adjoining the capillary can pass to the blood, but that in the cells further away is likely to remain for a longer time by reason of slow conduction.

Experiment 12.—Two electrodes were placed on the extensor aspect of the forearm. The electrodes were 3 in. in diameter and their nearest edges were 1 in. apart. At the commencement of the diathermy the temperature under each electrode was 92°. After the diathermy the temperature of the skin under the centre of each electrode had risen 8°, and under the edges which were nearest together the temperature rose 21° (to 113). The erythema was most evident in the regions where the temperature was highest, and it was not apparent where the electrodes were furthest apart.

This experiment illustrates the so-called "edge effect" to which reference has already been made. The skin temperature was much higher where the electrodes were closest together. It is very unlikely that the temperature rose more than a trivial distance below the skin even in the region where the highest surface temperature was obtained.

Experiment 13.—One electrode was placed on the patella and another on the popliteal space. They were of the same area. A current of 1·5 amperes was passed for ten minutes. The temperature under the former electrode rose 14° (from 78 to 92). That under the latter rose 7° (from 91 to 98).

Experiment 14.—One electrode was placed at the back of the elbow, the other on the anticubital fossa. A current of 1·4 amperes was passed for ten minutes. The temperature at the side of the olecranon rose 12° (from 83 to 95); that of the anticubital fossa rose 9° (from 89 to 98).

These experiments show that when the current passes through tissues of different resistance grouped *in series* it heats those of high resistance through a higher range of temperature than those presenting a lower resistance.

Practical Conclusions.—The above-described experiments show the dissimilarity of the temperatures obtained in different parts of the path of the current, and the slight rise obtained in the interior of the pelvis. They also show that there is a general rise of temperature when the current is applied locally.

If it is desired to raise the general temperature the current should be passed along the limbs. The latter will be heated

directly, by the current, and the thoracic and abdominal viscera and the contents of the cranium will be heated *indirectly*, by convection from the limbs. If the current is directed along the upper limbs the general temperature will attain a higher degree than will be the case when the lower extremities are traversed by the current.

When a joint is to be subjected to diathermy the electrodes should be placed on opposite aspects. Care should be taken that they are, as far as possible, equidistant, so as to avoid the edge effect. If the current is passed longitudinally along a limb the major portion will pass along the better conducting tissues outside the joint.

With regard to the feet and hands, one electrode should be placed on the sole or palm and the other on the dorsum of the foot or the back of the hand.

CHAPTER IX

THE ACTION OF DIATHERMY ON THE BODY IN HEALTH

In this chapter the inability of the diathermy current to stimulate the excitable tissues is explained. The effect of diathermy on the circulation and blood pressure, on the respiratory exchange and on metabolism, and some experiments on animals are described.

When the current generated by the diathermy machine is passed through the body no sensation other than heat is perceived.[1] The readiest way of demonstrating this is to grasp a cylindrical electrode in each hand and set the machine in operation. Nothing whatever is felt at first, but as the strength of the current is increased, warmth is perceived in the wrists. As the current continues to flow the wrists are felt to become hotter, and, at the same time, warmth is perceived in the narrower parts of the forearms. Gradually the whole of the forearm and upper arm perceives the warmth, while the wrists and lower parts of the forearms become still hotter. Heat is now perceived in the rest of the body, particularly the face and chest. When the wrists become very hot a curious and unbearable sensation is felt in them, and the hands seem to lose their grip of the electrodes. Further heating cannot be tolerated and the current must be stopped.

The most striking feature of currents which alternate with high frequency is their inability to stimulate the excitable tissues. They can be passed through the body, and their strength increased to a degree which, in the case of constant or low-frequency currents, could not be tolerated, and yet no contraction of muscle will be noted and no sensation perceived. The sensation of warmth mentioned above

[1] Occasionally a sensation resembling that caused by the faradic current is felt, and slight contraction of the muscles is noted. This is usually due to dryness of the skin in contact with the electrodes, and can be abolished by slight damping of the skin. Sometimes the faradic sensation is due to an unduly wide spark-gap. When this is the cause, reduction of the width of the gap will remove the sensation.

becomes apparent later, but this is not due to direct stimulation of the nerves by the current. For many years there was no satisfactory explanation of this peculiar phenomenon. Modern research on the electrical excitability of muscle and nerve has, however, shed light on the subject. The power of an electric current to stimulate the excitable tissues is now known to depend not only on the *strength* of the current but also on the *duration* of its flow. When the duration of its flow becomes very short the current must be made stronger if it is to produce the same response. If the duration of its flow is still shorter the current must be made still stronger. When, however, the duration of flow falls below a certain critical period the current loses its power altogether, whatever its strength may be, to stimulate the excitable tissues to give their customary physiological response. The high-frequency current flows for less than this critical period of time before it reverses, and is therefore unable to stimulate the excitable tissues. The warmth which is felt when the high-frequency current traverses the body is due to the actual generation of heat in the tissues while the current overcomes their resistance. To generate perceptible heat the density of the current (*i.e.* its strength per unit cross-sectional area of path traversed) must be high. If it is low, no sensation of any kind will be perceived.

A high-frequency current is also unable to produce any chemical (electrolytic) changes in the tissues. It flows for such a short time in either direction before reversal that it is unable to impart any movement to the ions in the tissue fluids. The ions therefore do not migrate to the electrodes and so cannot give up their electric charges and form new chemical compounds.

Some Observations on the Influence of Diathermy on the Circulation.

Local hyperæmia.—One of the most important physiological properties of the diathermy current is its power to cause active hyperæmia of the tissues through which it passes. The hyperæmia is caused, in part, by the dilatation of the blood vessels. Evidence of vasodilatation is shown by

the erythema of the skin under the electrodes. The degree of erythema, however, is surprisingly slight considering the temperature to which the skin may be raised. Thus, a patient whose forearm was being traversed transversely by the *galvanic* current, by way of an electrode placed on the surface, acquired a vivid erythema of the skin, and the temperature of the latter rose to 98·6°. The opposite forearm was subjected to diathermy. The skin under the electrode reached a temperature of 100°, but scarcely any erythema was visible. Even when the skin temperature was raised to 103° or 104°, the erythema was slight. The erythema induced by the galvanic current is due to vaso-dilatation reflexly produced by stimulation of the sensory nerve endings in the skin. The high-frequency current is unable to stimulate these nerve endings in the same way, and the slight erythema is due probably to direct warming of the subcutaneous vessels.

The hyperæmia is due also to a diminution of the resistance encountered by the blood in its passage through the arterioles and capillaries. Heat lessens the viscosity of the blood, thereby enabling it to pass through the vessels with less frictional resistance. The circulation is therefore accelerated and the heated region receives more blood per unit of time. By reason of the slight degree of vaso-dilatation it seems likely that the diminution of the viscosity of the blood is the more potent factor in causing the hyperæmia. The heated parts not only hold more blood, but the supply is more rapidly renewed.

Influence of diathermy on the arterial blood pressure.—The arterial blood pressure is influenced by various physical factors, *viz.* the force and rate of the heart beat, the peripheral resistance to the blood flow (especially that encountered in the arterioles, capillaries and small veins), the elasticity of the vessel walls, and the amount of blood in the system. Diathermy cannot alter the amount of blood in the system and it is unlikely that it can modify the elasticity of the arteries. But it can diminish the peripheral resistance. Cardiac muscle is also influenced by heat; physiological experiments on animals show that, within physiological limits, the rate and force of contraction are increased by a

rise of temperature. For these reasons diathermy should influence the arterial pressure in normal subjects.

In order to obtain information on the subject the author applied diathermy to normal subjects and to patients who were without cardio-vascular disease or constitutional maladies. In some experiments the electrodes were placed on the chest, one on the præcordium and the other on the back. By this method the heart muscle, more particularly that of the anterior wall, was heated. In other experiments the current was directed along the limbs so as to heat the whole blood, the object being to lower the peripheral resistance to the circulation. It is impossible, however, to heat the blood in the periphery without heating the heart at the same time by convection. Also if diathermy is applied to the heart the blood in the organ is heated at the same time. But the duration of its stay in the heart is brief and it cannot be heated to the degree possible when the limbs are subjected to diathermy.

When diathermy was applied to the extremities the following results were obtained. When the pressure was low at the commencement, the diathermy produced little or no fall. If the pressure were higher at the commencement, diathermy was, in some cases, not in all, followed by a more pronounced fall. These were the results noted when the diathermy was applied for periods of twenty to thirty minutes, and the current not strong enough to produce unpleasant and oppressive heat. Before applying the diathermy, the patient was kept at rest, so as to allow the blood pressure to sink to a stationary value. The following experiments illustrate the above-mentioned effects. In the first, the pressure, which was low at the commencement of the diathermy, was only slightly reduced, even after a long application.

Experiment 1.—The patient (M. B., *æt.* 21), who suffered from arthritis, was subjected to general diathermy, the current being passed along the upper limbs. The following changes in the systolic blood pressure were noted :

Before diathermy	94 mm.
After 10 minutes	90 mm.
After 25 minutes	90 mm.
After 30 minutes	95 mm.
After 35 minutes	88 mm.

At the end of the diathermy the oral temperature had risen 0·4°, the axillary temperature 1·2°, and the groin temperature 0·4°. The patient felt comfortably warm after the treatment. The fall of pressure was slight, only 6 mm.

Experiment 2.—On another occasion diathermy was applied to the same patient in the same way, but a stronger current was used. Before diathermy the pressure was 98 mm. After thirty minutes the patient complained of faintness and felt dizzy. The pressure was measured and found to be 65 mm. The patient felt uncomfortably hot and the oral temperature had risen 1·4° (from 98·6 to 100). A fall as low as this is rare, in the author's experience.

In the next case the pressure was relatively high before the diathermy. It fell 18 mm. during the diathermy.

Experiment 3.—The patient (M. P., *æt.* 17), who had suffered from a habit chorea, and presented no signs of cardio-vascular disease, was subjected to diathermy in the same way as the case mentioned above. The following changes in the systolic pressure were noted:

Before diathermy	128 mm.
After 10 minutes	118 mm.
After 30 minutes	112 mm.

When diathermy is applied to the *normal* subject in sufficient amount to raise the internal temperature, the results which the author usually found were a lowering of the systolic pressure and an increase in the pulse rate.

In the following observation the subject (female *æt.* 30) was placed on the diathermy condenser couch [1] and allowed to rest there, holding the electrode in both hands, so that the current was directed along the upper limbs. The apparatus was first set in operation, but no current was passed at first, in order to allow the pulse rate and pressure to reach a stationary value, and allow any psychic influence to subside.

Experiment 4.—	Temperature.	Pulse.	Systolic pressure.
At beginning of observation ...	98·6	104	140
After 5 minutes' rest	98·6	92	120
After 10 minutes' rest	98·6	92	120
After 5 minutes' diathermy	98·8	102	116
After 10 minutes' diathermy	99·4	106	112

The figures above show that after ten minutes the pulse rate increased by 14 beats per minute, and that the pressure fell 8 mm. The temperature rose 0·8°.

In the next observation (female, *æt.* 25), diathermy was applied in the same way as described above, but the current

[1] This method of applying diathermy is described on p. 131.

was allowed to flow for twenty minutes after the pulse rate and pressure had reached a stationary value.

Experiment 5.—	Temperature.	Pulse.	Systolic pressure.
Before diathermy	98·6	84	122
After diathermy for 7 minutes ...	99·2	92	115
After diathermy for 14 minutes ...	99·6	94	106
After diathermy for 20 minutes ...	99·8	94	104

In experiments of the kind described above the action of the diathermy is mainly on the peripheral circulation, that in the upper extremities being influenced *directly*, and that elsewhere being influenced *indirectly* by the heated blood. The action tends to *lower* the arterial blood pressure. On the other hand, the indirect heating of the heart by the blood in its passage through the cardiac chambers and coronary arteries increases the force and rate of the heart beat and tends, therefore, to *raise* the blood pressure. In the experiments above described the net result, when the diathermy was given in amount sufficient to raise the body temperature one or more degrees, was to lower the systolic pressure and increase the pulse rate.

In the next set of experiments the current was directed through the heart. By reason of its situation and the presence of additional paths for the current around the organ it is doubtful whether the heart, except the anterior wall, can be heated more than a trifling degree. The blood that passes through the heart cannot attain a temperature as high as that which it reaches in its passage through the heated extremities. Hence when diathermy is applied to the heart its effect on the blood pressure should, theoretically, be the result of heat mainly on the heart.

In Experiment 6 an electrode equal in area to that of the præcordium was placed over the heart. The current was increased until the skin under the electrode was as hot as could be borne without pain. The following figures were obtained :

Experiment 6.—	Temperature.	Pulse.	Systolic pressure.
Before diathermy	97·8	74	108
After 5 minutes' diathermy ...	97·8	78	108
After 10 minutes' diathermy ...	97·9	76	102
After 15 minutes' diathermy ...	98·0	72	106
After 20 minutes' diathermy ...	98·0	80	108

In this experiment the internal temperature rose only 0·4° F., and the systolic pressure and pulse rate were inappreciably altered.

In the next experiment a larger electrode was applied to the præcordium with the object of passing a stronger current and obtaining a higher internal temperature.

Experiment 7.—	Temperature.	Pulse.	Systolic pressure.
Before diathermy	... 97·2	80	130
After 5 minutes' diathermy	... 97·3	80	126
After 10 minutes' diathermy	... 97·9	80	120
After 15 minutes' diathermy	... 98·3	84	116
After 20 minutes' diathermy	... 98·4	86	116

The pulse rate increased by 6, and the systolic pressure fell 14 mm. The internal temperature rose 1·2°.

The *fall* of the systolic pressure was due, perhaps, to the fact that a portion of each lung was included in the circuit by using a large electrode. The lungs are highly vascular, and if they are subjected to diathermy the blood is heated and the peripheral resistance to its flow diminished.

It seems, then, that when diathermy is applied to the normal subject, either to the peripheral or central regions of the circulation, and in amount sufficient to raise the internal temperature one or more degrees, the results are a fall of the systolic pressure and an increase of the pulse rate. Occasionally, however, a slight fall of pressure was obtained without increase of the pulse rate. In one experiment a small *rise* of pressure was observed (the pulse rate remaining unchanged) when a slight degree of diathermy was applied to the heart.

Accurate observations on the influence of diathermy on the blood pressure are not easy to make. The psychic effect of the machine and of the measurement can easily explain a rise of pressure and increase of pulse rate, and obscure any effect which the diathermy may cause. The fall of pressure and increase of pulse rate are frequently slight, but as these changes have been noted in a fair proportion of normal subjects, when precautions were taken to remove extraneous influence, the changes above noted may reasonably be regarded as the effect of diathermy on the normal cardiovascular system.

Influence of Diathermy on the Respiratory Exchange and Metabolism.

Some interesting observations were made on the respiratory exchange during and after diathermy by Réchou (quoted by Bergonié, *Archiv. d'Élect. Méd.*, March 10, 1913). After diathermy for thirty minutes the subject was consuming less oxygen and giving off less carbon dioxide. At the beginning of the diathermy the oxygen intake and the carbon dioxide output both increased. Before the diathermy the oxygen consumed (during ten minutes) was 2·95 litres. At the beginning of the diathermy, the oxygen consumption was 3·63 litres, but after the diathermy had lasted for thirty minutes it fell to 2·14 litres. The figures for the carbon dioxide output were—before diathermy, 2·62 litres; at the beginning of diathermy, 3·16 litres; after thirty minutes' diathermy, 1·96 litres. The volume of oxygen inhaled is a measure of the metabolism of the body. The observations of Réchou show, therefore, that the first effect of diathermy is an increase of metabolism. The final effect, however, is a diminution of metabolism below that which occurs before the commencement of diathermy.

It is interesting to recall the earlier work by d'Arsonval on the influence of high-frequency currents on metabolism. It was shown by this distinguished pioneer that the metabolic changes were increased. The increase was due, doubtless, to the stimulating action of the small amount of heat produced in the body by the earlier high-frequency current-generator. The physiological fire was fanned and made to burn more fiercely. On the other hand, the large quantity of heat produced by the modern diathermy machine lessens metabolism, although the first action of the heat, before sufficient time has elapsed for its production in large amount, is to increase the metabolism.

The production of heat by the body in order to replace that which is being continuously lost is the result of katabolic changes. If the heat is supplied artificially by the diathermy current the katabolism is lessened, although the first effect of the heat is to increase it, as shown by the experiments of d'Arsonval and Réchou.

Réchou found acetone in the urine of adipose subjects after applications of diathermy.

Experiments on Animals.

Some experiments were made by Nagelschmidt to ascertain the effect of diathermy on different organs of animals. The results were published in his *Lehrbuch der Diathermie*. In some of these, the exposed heart of a dog was subjected to diathermy by means of electrodes placed directly on the organ. The effect of raising the temperature of the muscle was at once to accelerate the rate of heat. In some cases the rate was doubled. At the same time the blood pressure rose. After the cessation of the diathermy the pressure began to fall and the pulse rate to decrease, and in a few minutes both reached their original values.

In another experiment one electrode was placed on the spine, the other on the sternum, of a narcotised dog. The effect of the diathermy current (500 milliamperes) directed antero-posteriorly was to cause, after twenty seconds, a slight rise of blood pressure. It stayed at a constant level during the diathermy and slowly fell after the diathermy was discontinued. When the electrodes were placed on the lateral aspect of the thorax, one on each side, the amplitude of the respiration was slightly increased while using the same strength of current. When the current was increased to 1,700 milliamperes the respirations were deeper and slightly less frequent. The pulse rate was slightly accelerated. After the diathermy the respiration regained its former character. The temperature in the mediastinum rose 3·6° F. Further increase of the current deepened and markedly slowed the respiration, and, finally, breathing stopped. The mediastinum temperature now was raised by 7·2° F.

The temperature of the brain can be raised in the living animal by diathermy when electrodes are placed on the exterior of the skull. Cloetta and Waser (*Archiv für Experimentale Pathologie und Pharmakologie*, June 25, 1914) showed a rise of one degree Centigrade in the lateral ventricle of a dog after diathermy for ten minutes. The temperature fell to normal in ten minutes after stopping the diathermy.

Nagelschmidt applied diathermy to the medulla oblongata of a dog, and the respirations assumed a deep gasping character, probably from heating of the respiratory centre.

CHAPTER X

MEDICAL DIATHERMY

This chapter is divided into four main parts. In Part I medical diathermy is defined, and its mode of action in the treatment of disease, its therapeutic properties and the contra-indications against its use are considered. In Part II are described various methods of applying diathermy to the body, both locally and generally. In Part III the subject of dosage is considered. Part IV deals with the therapeutic field of medical diathermy: under the headings of the different systems of the body the maladies which are suitable for diathermo-therapy and the results which may be obtained are described. Special methods of applying diathermy to special regions are explained.

Part I

Definition.—By *medical* diathermy is meant the heating through of the body in disease to a temperature insufficient to destroy the tissues or impair their vitality. Medical diathermy may be either local or general. The use of the term "diathermy" signifies that the high-frequency oscillatory current is used to produce the heat.

The Action of Diathermy in Therapeutics.—The therapeutic effects which follow the passage of the diathermy current through the body are those of heat. Diathermy can cure disease or relieve symptoms where other forms of thermo-therapy have failed, because the heat generated by the electric current has a distribution different from that following heat applied by other methods. When diathermy is applied locally the tissues traversed by the current are heated through and through; at the same time other parts of the body can be heated to a considerable degree by convection. In other methods of thermo-therapy the heat is mainly restricted to the superficial regions; other parts of the body may be heated by convection, but to an inappreciable degree, unless a considerable area is exposed and the skin heated to a relatively high temperature.

It serves no useful purpose to assume that high-frequency

currents capable of producing diathermy can cure or relieve disease in any other way than by the production of heat. In maladies in which the therapeutic value of diathermy is established the effects of the treatment can be satisfactorily attributed to the production of heat. The hypothesis that they are due, partly or wholly, to some other action of the current, as, for example, " massage of the protoplasm " by the oscillating ions, affords no guide to the selection of maladies suitable for treatment. It must be remembered that the inability to find explanations—other than those which themselves required explaining—of the method of action of high-frequency currents on the body in the days when they were first used for treatment caused high-frequency treatment gradually to fall into a " slough of despond " from which it was rescued only when it was established that the therapeutic effects of these currents were due to the production of heat.

Therapeutic Properties of Diathermy.—In the relief of congestion and chronic inflammation diathermy is a valuable form of treatment, especially when the cause responsible for them, *e.g.* trauma, is no longer acting. The relief is due, doubtless, to the acceleration of the blood and lymph flow through the affected part. In this way the absorption of inflammatory products, especially the exuded fluid, is aided.

When *chronic* inflammation is due to infection the application of diathermy is frequently of value, because it induces active hyperæmia of the infected part, and by heating the tissues it increases their power to rid themselves of the infecting organisms. When the lethal temperature of the latter is low, diathermy is a potent therapeutic agent. The best example is seen in the treatment of infection by the gonococcus. The pneumococcus and diphtheroid bacillus are said to have a low lethal temperature, and diathermy possesses undoubted value in the treatment of lobar pneumonia and of infection of the cervix uteri by the last-mentioned organism.

It is probable, however, that the action of diathermy is not wholly on the organisms themselves. The termination of the infection is due also to the action of the heat on the infected tissues and the blood within them. Clinical

experience shows that gonococcal infection can be brought to an end by raising the tissues to a temperature, the degree and duration of which are insufficient to kill cultures of the organism. There is also evidence that the streptococcus fæcalis, an organism which possesses a high lethal temperature, can be destroyed *in vivo*, *e.g.* in the cervix uteri, by subjecting the living tissue to diathermy and raising it to a temperature much less high than that which will kill the organism in culture.

In procuring relief of pain diathermy is an agent of high value. When the pain is due to congestion the affected region can be heated in its entirety, and it is obvious that diathermy will be more effective than surface heating. When it is due to neuritis, the pain is frequently relieved by applying diathermy to the cutaneous areas to which it is referred. Relief can often be obtained when surface heating is ineffective.

Pain associated with contraction of muscle can usually be relieved by diathermy. The application of the treatment to the anal sphincters and rectal muscle in cases of fissure of the anus and hæmorrhoids is followed by relief, and it is likely that the alleviation of the pain is due to the quieting of spasmodically contracting muscle.

Dysmenorrhœa of the painful contraction type is relieved by subjecting the interior of the pelvis to diathermy. If the treatment is given for a few days before the onset of menstruation the period is usually painless. In dysmenorrhœa of the painful congestion type diathermy is equally effective.[1]

Diathermy is a form of treatment of recognised value in cases of abnormally high blood pressure. The latter can be lowered and the accompanying symptoms, when present, are relieved. It is likely that the heat lessens the viscosity of the blood, thereby lowering the peripheral resistance to the circulation and relieving the heart of some of its work. Diathermy may also lessen the tone of the arterioles when the calibre of the latter is diminished by undue contraction of the muscle coats.

[1] It is possible that the relief of dysmenorrhœa is due to the action of diathermy on the endocrine function of the ovaries. Further reference to this subject will be found later (p. 162).

Among the most valuable therapeutic properties of diathermy is that of elevating the body temperature when the latter is below that which is normal for the individual under treatment. The artificial administration of the heat which the body cannot supply is followed by relief of malaise and discomfort, and the feeling of chilliness soon disappears. The body weight sometimes increases after a course of diathermy in cases of this kind.

The symptoms which arise from certain maladies are aggravated if the body temperature is unduly low. The application of general diathermy will sometimes procure relief even if the site of the disease is not directly included in the treatment.

Contra-indications against Diathermy.—It is unsafe to apply diathermy to regions from which hæmorrhage has recently occurred (or is likely to occur) if the cause of the bleeding is not under complete control. The active hyperæmia induced by diathermy may start the hæmorrhage afresh. It would therefore be unwise to apply the treatment to the lungs after recent hæmoptysis or to the stomach after hæmatemesis.

Some authorities regard diathermy as inadvisable in *acute* infection and *recent* injury. If the presence of pus is proved or suspected, diathermy should not be applied to the affected region. In certain acute infections, however, diathermy may be given. In acute gonococcal epididymitis the pain and symptoms are rapidly relieved, and although cases are known to the writer in which the application of the treatment to one region was followed by the development of symptoms in another part the control of gonococcal infection by diathermy is sufficiently complete to render the treatment safe and valuable.

In lobar pneumonia, too, the use of diathermy seems to be without risk, and the treatment procures considerable amelioration of symptoms.

Diathermy should not be administered during menstruation. Theoretically there is a risk of increasing the loss of blood. When, however, there is a continuous slight bleeding after the date when the menstruation should normally stop, there is no contra-indication to the application of diathermy

to the pelvic organs. The treatment is likely to procure the desired effect and stop the bleeding. Further reference to this subject will be made later (p. 162).

The power of diathermy to lower the arterial blood pressure renders the treatment inadvisable, in the opinion of some authors, for cases in which the pressure is unduly low. Syncope is feared in such cases. Accidents of this kind have not occurred in the author's experience. Although there is the theoretical risk, it will not be realised if due watch is kept on the patient and the treatment administered with care.

While anæsthesia of the skin is not an absolute contra-indication against the application of diathermy, the treatment should be given with anxious care. When the skin or mucous membrane has lost its power of perceiving heat the patient is unable to give information when the degree of heat is approaching or passing beyond that which will cause damage to the tissues. Instructions for avoiding burns in cases where the electrodes are applied to regions insensitive to heat will be given later (p. 127).

Part II. Methods of Application

(1) Local Diathermy.

Electrodes.—The simplest and most generally used are metal plates of various sizes. Each is provided with a clip or terminal for attachment of the cable which connects it with the diathermy machine. They are made of lead or a tin alloy and are sufficiently thin to allow easy pliability.[1] The following are useful stock sizes :

Circular. $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ inches in diameter.

Rectangular. $2\frac{1}{2} \times 4$; $2\frac{1}{2} \times 3\frac{1}{4}$; $3\frac{1}{4} \times 5$; 4×6; 5×7; $5 \times 8\frac{1}{2}$; $2\frac{1}{2} \times 13$; 3×16.

Square. 2×2; 3×3; 4×4.

(The figures are given in inches.)

[1] The author uses sheet lead 1 mm. thick. This is sufficiently pliable and is easily kept in contact with the body by an Esmarch bandage. Some workers use thinner sheets and secure them in position by roller bandages.

Special electrodes are used in the treatment of less accessible regions, such as the rectum, uterus, etc. These will be described when the application of diathermy to these parts is considered.

Application of Electrodes to Skin.—To ensure accurate contact between the metal plate and the skin the latter should be moistened with water or lathered with soap. If the skin is hairy the soap lather is essential.

If the skin is unduly dry and the metal plate placed in contact without moistening the epidermis, the patient will feel a sensation resembling that produced by a mild faradic current. The covered regions of the body are usually moist enough to prevent the faradic sensation, but it is advisable to damp the skin or apply the lather under the active electrode.

The author prefers to interpose a moistened pad between the electrode and skin. The pad is made of folded towel cloth and is well soaked in 10 per cent. salt solution. A half of an inch is a suitable thickness. The interposition of this pad has certain advantages. Uniform contact with irregular surfaces is easier to make. The preliminary moistening of the skin is unnecessary. The salt solution lowers the resistance of the horny layer of the skin, thereby rendering the diathermy less uneven.

Some workers object to the insertion of a moistened pad between the metal and the skin. They say that the temperature of the pad will rise more than that of the skin and cause burning. This will certainly happen if the pad is soaked in *tap water* or in *salt solution of insufficient strength*, because the resistance of the pad is higher than that of the skin. The current, therefore, will heat the former to a higher degree than the latter. The progressive rise of temperature of the pad can be studied by placing a thermometer with its bulb in the pad. If, however, the pad is soaked in *strong salt solution* its temperature will rise, but *pari passu* with that of the skin. Two tablespoonfuls of salt to a pint of water will make a solution of amply sufficient strength.[1]

[1] Kowarschik performed some experiments, which he describes in his book *Die Diathermie* (5th edition, p. 52), in order to ascertain the effect on the temperature when moistened pads were interposed

Situation of the Electrodes.—Certain rules must be followed when deciding the situation of the electrodes. It has already been shown in the chapter on the path and distribution of the diathermy current that the electrodes must be placed in definite relation to each other and to the part requiring treatment if uniform heating (as far as this is possible) is to be obtained (pp. 96, 107).

When both electrodes are applied to the skin they should be placed on *opposite* sides of the region to be treated. They should be placed in parallel planes, and the lines joining their corresponding parts should be as near as possible at right angles to the surface. If these rules are not followed there will be considerable inequality of the heating of the tissues between the electrodes, and the edge effect may be produced.

If a region (*e.g.* the shoulder) is to be heated in its entirety the electrodes should be equal in area. Both electrodes are then "active." If the part to be heated lies approximately midway between opposite surfaces the electrodes should be of the same area. If the part is not equidistant, but has a relatively superficial situation (*e.g.* the heart, hip-joint, etc.) one electrode (active) should be placed on its surface marking and the other on the opposite aspect of the trunk or limb. The latter electrode is better termed the "directing" than the "inactive" electrode, because its correct situation ensures the distribution of the current in the part desired. It should have a larger area than the active electrode.

When a joint is to be treated it is undesirable that the

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between the metal electrode and the conductor. The conductor was composed of clay made up into a block with salt solution. Metal plate electrodes were placed on opposite aspects and a diathermy current was passed through. In the first set of experiments the electrodes were placed in direct contact with the clay. Only a slight difference of temperature was found between the surface and the centre. In the second set of experiments he interposed moistened pads of filter paper between the electrodes and the clay. A much higher temperature was recorded on the surface than in the centre. The reason for the greater heat on the surface was doubtless due to the use of "customary water" (*gewöhnliches Wasser*) with which the pads were soaked. These pads had a higher resistance and were heated to a higher temperature than the clay. If they had been soaked in strong salt solution the difference would not have been noted.

electrodes should encircle the limb above and below the articulation. Attention has already been drawn to the concentration of heat in the soft tissues outside the joint when the current is directed *longitudinally* along the extremities. The current should be directed *transversely* across the joint by way of plate electrodes applied to opposite aspects. Where the joint is round rather than flat in cross section (as is the case with the knee) the width of the electrodes should be one quarter of the circumference and placed first on the anterior and posterior aspects, and afterwards on the lateral aspects. In this way the edge effect, which would occur if wider electrodes were used, can be avoided.

In those regions where the limb is flatter in cross section, such as the wrist and elbow, the electrodes need only be placed on the anterior and posterior aspects. Similar positions should be adopted in the case of the shoulder. In the case of the ankle they should be placed on the lateral aspects. To treat the sterno-clavicular and hip joints one electrode (active) should be applied to the superficial aspect. The directing electrodes should be placed respectively on the back of the thorax and the buttock. In the case of the finger and toe joints the electrodes should be placed on the flexor and extensor aspects. One or more of these joints can be included between the same pair of electrodes. To treat the spinal column and cord one electrode should be placed over the vertebral column and the other on the anterior aspect of the trunk in the middle line. The most effective way of subjecting the hand to diathermy is to place the electrodes on the palmar and dorsal aspects. In the case of the foot one electrode should be placed on the sole and the other on the dorsum. If attempts are made to heat both feet simultaneously by placing an electrode on each sole and directing the current along the lower limbs, the anterior parts of the feet will not be heated. To subject the brain to diathermy the electrodes may be placed on the temporal regions, or on the forehead and occiput. The hair must be well lathered with soap and water.

Methods of applying diathermy to the urethra, uterus, uterine appendages, rectum, prostate, and other regions will

be described in the sections dealing with the treatment of these parts.

Regulation of the Strength of the Current.—When diathermy is to be applied to parts under the skin and superficial fascia it is very important that the current should be *slowly* increased. The tissues do not at once reach the maximum temperature that the current can produce. The current, therefore, should not be quickly increased to the maximum required. It should reach this strength in stages and fifteen to thirty seconds should elapse between each increase. If the current is rapidly increased to its maximum in one stage the highly resistant fat in the superficial fascia will quickly become too hot and the current will have to be stopped before the better conducting tissues under the deep fascia have had time enough to become sufficiently hot.

It is also possible that a quick rise of temperature of the skin may influence the sensory nerve endings in the skin and cause reflex vaso-dilatation in the deep-lying organs. If this occurs and the vessels dilate, a larger quantity of blood will pass through the parts which they supply. More heat will then be lost by convection and the parts will not attain the temperature which could be reached if no vaso-dilatation occurred.

The maximum current which can be applied to a region is determined by the degree of heat that the tissues can tolerate without damage. If there is no diminution of sensation, the patient's feeling is a safe guide to the degree of heat that can be applied without risk. It is not often necessary to heat the skin to the maximum temperature which the patient can bear. The current which produces a comfortable warmth is generally sufficient.

The patient should always be told to give notice when he first feels the sensation of heat. Further increase of the current should then be delayed, because the sensation will increase a little, even if the current strength remains stationary. As soon, however, as the patient feels that the heat is no longer increasing the current may then be increased. This procedure is repeated until the patient feels a comfortable warmth. Further increase of the current makes the skin feel hotter and a stage is reached when pain is felt in

the skin as well as heat.[1] At this stage the skin is likely to be damaged if the current is not reduced until the pain disappears.

The patient should always be told to give notice if any part of the skin under the electrode becomes uncomfortably hot. The electrode should then be removed and the skin examined and felt by the operator. The first visible sign of unsafe heating is the appearance of a deep erythema (unlike the pink flush which is produced by the safe maximum heat). Œdema may then develop at the spot where the erythema is most intense and a blister form.

If there is any doubt of the patient's power to perceive the sensation of heat it is advisable to test the skin with hot water in a test tube. If heat sensation is lessened it is advisable to remove the electrode from time to time and feel the degree of warmth of the underlying skin without trusting to the patient's sensation. This precaution is absolutely necessary when there is complete anæsthesia of the skin. Indeed, in such cases it is inadvisable for those who are inexperienced to apply diathermy.

Condenser Electrodes.—These are made of glass and have various shapes (tubes, cones, etc.) and various sizes (Fig. 43). They are partly exhausted, so that the residual air becomes a fairly good conductor. A short platinum wire is sealed into one end. Any one of these electrodes can be attached to an insulating handle which is grasped by the operator. When attached the platinum wire is brought into connection with a terminal secured to the handle. The terminal is connected to one of the cables from the diathermy machine. The glass is placed in contact with the part of the body requiring treatment. The circuit is completed by means of an indifferent electrode. When the current is switched on and increased to a suitable strength the residual air in the glass electrode glows with a violet light and the tissues in contact soon become hot.

[1] When neuritis accompanied by pain is being treated by diathermy the patient will sometimes feel an increase of the pain during the passage of the current, even though the skin under the electrode is not unduly hot. This, however, is not the pain of overheated skin, and it may be felt, in addition, in areas other than that covered by the electrode.

If the electrode is applied to the skin the latter soon acquires a vivid erythema. Its glands are stimulated and the glass is soon covered with their dried secretion. In this method of applying the current through the skin the degree of diathermy of the deeper tissues is probably but slight. Strong currents cannot be used because the fine sparks, which have the appearance of a thin blue filament between the glass and skin, heat the epidermis strongly. These sparks, however, stimulate and increase the secretion of the sebaceous and sweat glands. They also form ozone and oxides of nitrogen from the air through which they pass. These

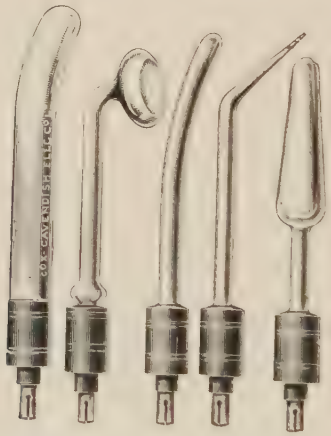


Fig. 43.—Glass condenser electrodes. (The so-called "vacuum" electrodes.)

gases are germicidal and exert this action in the superficial layers of the epidermis. After a short application of the electrode a strong odour of these gases can be noticed in the skin.

The electrode is usually rubbed over the skin while the current is passing. A stronger current can then be applied without excessive heating of the skin, and a larger area treated in a shorter time.

Condenser electrodes of suitable size and shape are made for use in the rectum, vagina, nose, etc. It must be remembered that when the glass is placed in contact with moist mucous membranes sparks do not pass between the glass and

the tissues with which it makes contact. The glass makes perfect apposition with the moist mucous membrane and no air is included between the parts in contact. The same is not the case when the electrode is applied to the dry skin. The glass does not make perfect contact. A thin film of air exists between the electrode and the skin, and sparks pass across the gap.

The stimulating and disinfecting effects which occur when the condenser electrode is applied to the dry skin are not obtained when electrodes of this type are used for the treatment of parts covered by moist mucous membranes. Only diathermy is obtained, and the degree of diathermy is only slight because the glass soon becomes quite hot even when a comparatively slight current is used. The reason for the heating of the glass is the high temperature which the residuary air in the electrode attains when the current passes through it.

Hence when condenser electrodes are applied to mucous membranes a slight degree of diathermy of the underlying parts is obtained while the epithelium is heated superficially to a much higher degree. If it is desired to obtain a more even degree of heating of the superficial and deep parts alike a metal electrode should be used.

Electrodes of the type above described are usually known as "vacuum electrodes" because they are partially exhausted. If they contained a complete vacuum they would not conduct the current.

Other types of condenser electrode are made. One consists of a glass tube filled with oil and contains a metal rod which occupies the position of its long axis. In this electrode the glass and oil act as the dielectric of the condenser and the metal rod as one of the armatures. By reason of the thickness of the dielectric the current supplied by the diathermy machine must be at a high voltage. These electrodes are strongly constructed and have been used for combining massage with the effects of the condenser.

In another type the oil is replaced by powdered graphite. The latest type—and, in the opinion of the author, the best—is the so-called "non-vacuum." These are made of glass but contain air at atmospheric pressure. The inner

surface of the glass is lined with silver and the latter is brought into connection with a hook which is secured to the glass. The hook serves for attachment of the cable from the diathermy machine.

In this electrode the silver lining takes the place of the rarefied air as the internal armature. It has a much lower resistance. Although the violet glow [1] seen in the interior of the "vacuum" electrode is not observed when the non-vacuum type is used, there are the advantages that the latter is less easily broken and the glass does not become so hot.

Diathermy applied by means of the condenser electrode is of considerable therapeutic value in acne vulgaris and septic infection of the skin and sebaceous glands. It is sometimes successful in chronic ulcers due to infection where other forms of treatment have failed.

Electrodes for less accessible Regions.—Special electrodes have been made for applying diathermy to the lower end of the rectum, the vaginal wall, the uterus and its adnexa, prostate and seminal vesicles, testis and epididymis, and the urethra of both sexes. These will be described when the treatment of these parts is described.

(2) General Diathermy.

The simplest way of applying diathermy to the whole body is to pass the current first along the upper limbs by way of cylindrical electrodes grasped in the hands, and afterwards along the lower limbs by way of plate electrodes applied to the soles of the feet. By this means the limbs are

[1] It may be mentioned here that the violet light plays no part whatever in the production of therapeutic results except in so far as it may impress the mind of the patient. If any ultra-violet rays are produced they will not pass through the glass. Small portable models of high-frequency current generators are made for use with "vacuum" electrodes and the administration of what is improperly called "violet ray treatment." This treatment, applied by means of the small generators, has the effect of heating and stimulating the skin. A small quantity of ozone and oxides of nitrogen is formed. This treatment is popular among barbers. The strength of the current is very small, and when it is applied by metal electrodes the *diathermy* is so minute as to be almost valueless except when minute portions of the body are treated.

heated *directly* by the current, and the trunk, neck and head *indirectly*, by convection, by means of the blood which is heated in its passage through the extremities. Strictly speaking, the trunk, neck and head are not subjected to diathermy in the same way as the extremities, because the current does not pass through them except in the pelvis and upper parts of the chest. They can, however, attain a higher temperature by convection than by passing the current through them and heating them directly.

A method used by some workers on the Continent is the following. Kowarschik applies a large plate electrode to

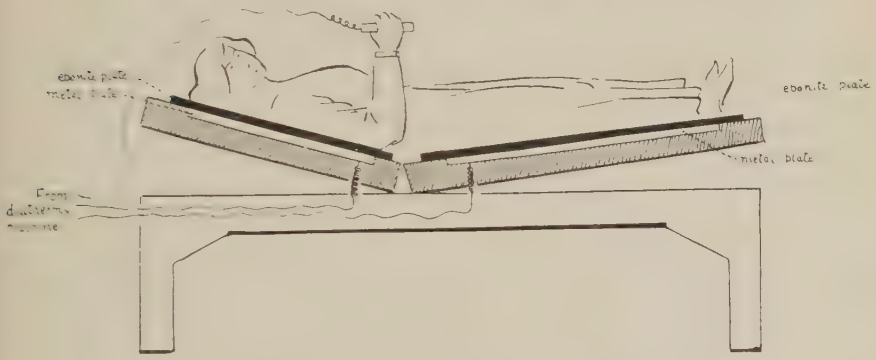


FIG. 44.—Condenser couch for use with diathermy current.

the back and connects it with one of the cables from the diathermy machine. The other cable is connected to two pairs of cuff electrodes which encircle the lower parts of the forearms and legs. By this method the trunk is directly traversed by the current as well as the limbs, but it has the disadvantage that extra time and trouble are taken in applying the electrode to the back, and the patient is more exposed to the atmosphere.

A third method, which, on the whole, is the most suitable and convenient, is one in which a condenser couch is used. Condenser couches for use with the high-frequency current generator of the d'Arsonval type have been employed for a long time. One suitable for the diathermy current was devised by Schittenhelm in June 1911. It is shown in diagram in Fig. 44. In shape it resembles a long low table.

It is made of wood. The top of the table is divided transversely into two parts and hinges secure the contiguous ends to the frame of the couch so that the ends can be raised, as shown in the figure.[1] The top of each division is covered with sheet ebonite. Under the latter are secured four metal sheets, two lying side by side under the upper division and two lying similarly under the lower division. At the head end of the couch is a box containing five crank switches. By means of these either of the metal sheets can be electrically connected to either pole of the diathermy machine. By means of the fifth switch either pole of the machine can be connected to the electrode which is applied to the patient.

When the condenser couch is used for the application of general diathermy, one of two methods may be adopted. In the first, and more usual, all four metal sheets are brought into connection with one pole of the diathermy machine. The other pole is connected to an electrode which is applied to the patient, the latter reclining on the couch. This electrode is usually a metal tube, about 18 inches long. It is grasped by the patient. In place of the metal tube a plate electrode may be placed on the sole of each foot and the electrodes connected by a short length of cable.

When the patient is on the couch he constitutes one of the armatures of a condenser. The metal plates under the ebonite, which, in this method of using the couch, are electrically connected, serve as the other armature, and the ebonite is the dielectric. When the machine is in operation the patient is charged alternately positively and negatively, the polarity changing with high frequency. The body, being one of the armatures of a condenser, can hold a larger charge. When some machines are used the amperemeter will indicate a larger current than that registered when both electrodes are applied to the body and the couch is not used. With other machines the reverse is the case. It has been stated (p. 28) that the maximum current is obtained in the resonator when the amount of self-induction in the latter multiplied by the capacity of the condenser in the resonating circuit is equal to the product of the same factors in the oscillating circuit. The introduction of a condenser with a larger capacity than that of the body by itself will disturb the balance, and the current in the resonating circuit will be lessened unless the machine is specially designed for use with the condenser couch.

When the patient is on the condenser couch and grasps

[1] It is more comfortable for the patient if the division which supports the lower limbs is also divided and hinged. It can then be bent and the patient can flex his knees and avoid the discomfort of full extension.

the rod electrode the current attains its greatest density in the upper extremities and these parts attain the highest temperature. The heating of the rest of the body is due to convection by way of the blood stream, and, in slight degree, to direct action of the current.

In place of the rod a metal plate electrode may be applied to other regions of the body and local treatment combined with general treatment. The degree to which the body as a whole will be heated will depend on the situation of the plate electrode. If it is applied to a part of the trunk, the current will traverse a broad region of the body which has a low resistance and heat it only a slight degree. The converse will be the case if the electrode is applied to a part of a limb, especially if it is placed near the distal end, thereby compelling the current to pass along a greater length of a narrow conductor.

The parts under the electrode receive *local* treatment. The current cannot, however, be restricted to them because there is no directing electrode on the opposite aspect of the region. The metal sheets under the ebonite act as an *indifferent* electrode, and the current density rapidly lessens as the depth below the surface increases. The skin, superficial fascia and the parts which lie a short distance below the deep fascia can, however, be subjected to a fair degree of diathermy. These parts can be treated on the condenser couch, and the time occupied in fitting an additional electrode is saved.

In the second method of using the condenser couch the patient reclines on the ebonite but no electrode is applied to the body. By means of the crank switches any two of the metal sheets under the ebonite are connected to one pole of the diathermy machine, and the two remaining sheets to the other pole. The body is then traversed by *induced* diathermy currents. Suppose the two sheets at the foot end on the couch are connected to one pole of the diathermy machine, and the two sheets at the head end to the other pole. Induced currents will then oscillate between the upper and lower portions of the body. The pelvis and lower extremities rest on the ebonite over the two lower sheets, and the upper extremities, head and neck, and the remaining portion of

the trunk rest over the two upper sheets. By suitably adjusting the switches in the changing box at the head of the couch the current may be made to oscillate either between opposite sides of the body, or between the upper and lower portions, or obliquely between the upper part of the body on one side and the lower part on the other.

In this method of using the condenser couch the whole of the body can be subjected to diathermy. The density of the induced currents is low and only a slight degree of heat is felt by the body. The parts of the body which make contact with the couch feel the most heat, particularly the hips and back.

Regulation of the Current in General Diathermy.—When general diathermy is to be given the current should be increased slowly and in stages, precisely in the same way as when local diathermy is given. When the current is directed along the upper limbs by way of electrodes grasped in the hands, the wrists, being the narrowest parts of the body circuit, attain the highest temperature. If the current is increased too rapidly the wrists quickly become too hot and the patient complains of an unbearable aching sensation in these joints and is soon unable to hold the electrodes. A similar sensation is felt in the ankles when the electrodes are applied to the soles and the current attains too great an intensity.

If the patient feels this sensation the electrodes should be removed and cuff electrodes applied to the forearms or legs. The cuffs should be connected by means of a short length of insulated cable when the condenser couch is used. Cuff electrodes should be used from the commencement if a high degree of general diathermy is desired.

When general diathermy is given the hands and feet are the last parts to feel warm and show a rise of temperature. They are heated mainly by convection, but as their temperature is usually subnormal a longer time is occupied in attaining the same degree of heat as the other parts of the body. If the hands and feet are abnormally chilly they may feel but little warmer at the end than at the beginning of a twenty minutes' séance. They gradually become warmer after the treatment is ended, but if coldness of the feet and

hands is a distressing symptom it is advisable to apply local diathermy to these parts at the conclusion of the general treatment.

Other Uses of the Condenser Couch.—It has already been stated that local diathermy may be given on the condenser couch. The metal plate under the ebonite takes the place of the directing electrode. The couch may be used for the application of diathermy to the more superficial regions, but the current cannot be restricted in the deeper parts.

The couch is particularly useful when condenser electrodes are used and the trouble of applying an indifferent electrode is avoided.

When the operator desires to combine massage with diathermy the condenser couch is very convenient (see p. 136). The couch is also necessary for the application of that form of surgical treatment known as "fulguration" (p. 235).

(3) Labile Method of applying Diathermy.

By moving the active electrode over the region to which diathermy is being applied certain advantages may be gained. It is likely that a more even degree of diathermy is procured if the active electrode is a quarter or a third of the area to which a stationary electrode would be applied, and maintained in slow rhythmic movement over the skin. The greater degree of diathermy which is produced in the parts near the edges of a stationary electrode can thus be avoided. By exerting pressure on the active electrode the latter can be brought nearer the deep tissues. This is possible when soft tissues are in relation to the region requiring diathermy.

For the application of labile diathermy a circular metal electrode may be used. A wooden handle is attached to one aspect for the operator to hold. The other aspect should be slightly convex. The skin is covered with soap lather and the electrode moved slowly over it. An alternative method is to use a padded electrode. A circular felt pad of the same diameter as the metal and a quarter of an inch thick is secured to the convex aspect by stitches (the metal being perforated for the purpose), and a piece of lint is wrapped round the felt and metal and tied by tape to the stem of the

handle which is held by the operator. The pad and felt are soaked in salt solution not less than 10 per cent. in strength.

By the labile method diathermy can be combined with some forms of massage. This is described in the next paragraph below.

(4) Combination of Diathermy and Massage.

There are four ways of giving the combined treatment. In some of the methods *general* diathermy is obtained as well as local.

(1) The first method is that described above. The directing electrode is placed on one aspect of the part to be treated and the massaging electrode is moved over the other. In this method the diathermy is almost entirely local and the amount of heat which spreads by convection to other parts is very slight.

(2) In this method the patient sits or lies on a condenser couch and the massaging electrode is moved over the region requiring treatment. The patient receives a slight amount of general diathermy if the massage is applied to the trunk. If it is applied to a limb the remainder of the body receives a larger amount of general diathermy.

(3) In this method the patient receives general diathermy by the condenser couch method described above (p. 131). A massaging electrode is not used, but the operator performs the desired manipulation with his finger-tips. In this method a small diathermy current passes between the body and the fingers of the operator. If the palm of the hand is applied the current density is lowered and less heating is obtained. If the finger-tips are lightly moved over the skin the contact is uneven and fine sparks pass between the parts which are in contact. In this way the effects of the condenser electrode are imitated in a slight degree. If firmer contact and pressure are made the sparks do not pass.

(4) In this method the Schittenhelm condenser couch is used. The two lower metal plates are connected to one terminal of the diathermy machine. The other terminal is connected to the two upper plates. The patient sits on the couch over the lower plates. The operator sits on the couch

over the upper plates, sets the diathermy machine in operation, places one hand on the region requiring treatment and then increases the current until the part in contact with his hand becomes warm. The massage is then performed. The hand should not be moved away from the patient, because sparks will pass directly it is lifted off. When the treatment has been completed the current should be reduced to zero and the switch closed before removing the hand.

The author has experimented with various methods of using the condenser couch in connection with diathermy, and has found the last method most efficient.

Part III.—Dosage in Diathermo-Therapy

It is erroneous to assume that the maximum degrees of diathermy are always the most effective in procuring therapeutic results. Minor degrees will produce better effects in certain maladies and in different stages of the same malady than higher degrees. Attention to dosage is no less important in diathermy than in other forms of therapy. Quite apart from the burns which may be the consequence of excessive current or improper application of electrodes, it is possible in some cases to do harm or at least to fail in procuring benefit by administering strong currents and heating the tissues to the maximum degree they can tolerate without the infliction of structural damage.

In the treatment of the pelvic, abdominal and thoracic organs the use of relatively weak currents and the production of a gentle degree of diathermy for a comparatively long period will produce better results than short applications of strong currents and the heating of the skin to the limit of toleration. This is true when the relief of pain and spasm is the desired object.

Attention is here drawn to some experiments conducted by Furstenberg and Schemel. It has already been stated that these authors were able to demonstrate a rise of temperature in the stomach by directing a diathermy current through the abdomen of a dog. They showed, in addition, that stronger currents produced a *slighter* rise

than weaker currents. This apparent paradox is explained by assuming that intense heating of the skin by strong currents caused a reflex vaso-dilatation of the gastric blood vessels and a removal of heat from the stomach by convection. When the animal was killed and the circulation stopped it was found that stronger currents produced a higher rise of temperature in the stomach, and *vice versa*. These experiments may explain why strong currents are less effective in relieving visceral pain.

In the treatment of pain due to peripheral neuritis the application of weak currents and the production of a mild degree of diathermy are more effective than strong currents, at any rate in the early stages. In chronic neuritis a stronger current is usually more effective.

In certain diseases it has been found that strong currents give better results. In the treatment of gonococcal infection of certain regions the author and his colleagues have obtained the best results by the use of currents increased to the limit of toleration and applied for relatively short times. The object here is the destruction of the gonococcus. When, however, the Fallopian tube is infected it is impossible, by reason of its deep situation, to heat it to a degree high enough to destroy the infecting gonococci. Diathermy can, nevertheless, be used with advantage, but for another purpose, namely, the relief of pain. Weak currents and a mild degree of diathermy are here just as effective as strong currents. The latter may, on the other hand, increase the pain, and the increase may last for a day or even longer.

In the present state of our knowledge of diathermotherapy it is difficult to lay down any precise and final rules regarding dosage. As a rough guide, however, the following general principles may be adopted, pending the acquisition of further knowledge.

For the production of sedative effects, such as the relief of pain and spasm, the degree of diathermy should be slight in the earlier stages of the infection or injury, and the duration of the treatment relatively long, *viz.* half an hour, three-quarters of an hour, or even longer.

At the onset of the case and in the acute stage it is generally inadvisable to administer diathermy unless the agent

responsible for the symptoms is an organism with a low lethal temperature, such as the gonococcus or, perhaps, the pneumococcus or diphtheroid bacillus. When organisms possessing a higher lethal temperature are responsible for the disease, or when the cause is obscure, diathermy may be commenced when the acute stage has passed. At first the degree of diathermy should be slight and its duration relatively long. As the case progresses the degree of diathermy may be increased and its duration shortened. In chronic cases, whether of infection or of trauma, the degree of diathermy may be high from the commencement of the treatment. In all cases where there is any doubt it is better to commence with slight degrees of diathermy and apply the treatment for about half an hour.

Regarding the *measurement* of the dose, it must be remembered that the amperemeter is an insufficient guide to dosage. This instrument gives an approximate measure of the current that passes through the body, but does not tell how much of the current energy is transformed into heat in the body. The resistance of the tissues must also be known. If a narrow, highly resistant part of the body, such as the forearm, forms the path of the current it can soon be heated to the limit of toleration, yet the amperemeter may not indicate more than 0·7 ampere. On the other hand, if a broad region of low resistance, such as the abdomen, is traversed by the current the amperemeter may indicate 2 or 3 amperes although little heat is being generated. In the case of the forearm a comparatively weak current produces a high degree of heat, whereas in the abdomen a current which is three or four times as strong heats the tissues a slight degree only.

The dose could be calculated from the reading of the amperemeter if the resistance of the tissues along the path of the current were known. Too little, however, is known of the resistance (impedance) of different regions of the body under different conditions to currents of different frequencies to render calculation a guide to the degree of heat that a current can produce. The most accurate guide to the measurement of dosage is the thermometer or other heat-measuring instruments such as the thermo-couple. The

internal temperature of the body as a whole can be measured, when *general* diathermy is given, by means of thermometers placed in the mouth or rectum. When *local* diathermy is given and the more superficial regions require the treatment, the temperature of the skin and of certain mucous membranes can be measured. The surface temperature gives a guide to that attained in the parts immediately underlying, and although it is only approximate, it is a more accurate guide than the reading of the amperemeter.

When it is desired to heat a region to the maximum degree the sensation of the patient will afford a guide to the prevention of damage to the tissues, always provided that there is no loss of sensation in the skin. When the current is directed across the trunk, or transversely across a limb, the skin and subcutaneous fat attain a higher temperature than the underlying parts. The maximum temperature which the skin can tolerate without pain may be taken as 114° F. (45·5° C.). This degree does not harm the normal skin, but pain is felt if it is exceeded. The sensation of pain may therefore be taken as a sign that the safe degree of heat is being exceeded. It indicates the necessity for reduction of the current until pain disappears.

When the current is directed longitudinally along a limb the maximum temperature is produced in the narrowest part, and a complaint, on the part of the patient, that pain or aching has developed in this part is an indication that the current has exceeded the maximum strength that is advisable.

When only slight degrees of diathermy are required in parts which lie at a considerable depth below the surface the only guide to dosage is the temperature attained by the skin under the electrodes. A weak current is one which raises the temperature of the skin slightly, not that indicated by the amperemeter. A strong current is one which heats the skin to a degree approaching the limit of toleration.

The amperemeter is useful, however, when the operator is accustomed to his diathermy machine and has learnt the degree to which the skin of different regions is heated when electrodes of known surface area are used. He can then record the strength of the current which heats the skin to a

slight or medium degree, or to a degree approaching or reaching the limit of toleration.

A statement that, say, 1·5 amperes should be applied for the treatment of a certain region conveys insufficient information. If the area of the electrodes is stated as well the information is of more value. Machines differ, however, and although the amperemeter of one machine may indicate the same current as that of another, the region which is treated may not attain the same temperature with both machines even though the size and situation of the electrodes are, as near as possible, identical. The temperature of the skin or mucous membrane (or of the deep parts where it can be measured) and the time for which the rise of temperature is produced are the only accurate measures of dosage.

Part IV. Therapeutic Field for Medical Diathermy

The diseases and symptoms which can be cured or relieved by heat are many. Some of them, or some examples of them, will respond to heat applied to the surface. Some will respond more quickly and satisfactorily to heat produced in the deep-lying regions than to heat applied to the surface. Some will respond only to heat produced in the deep-lying tissues, and in a few of these the treatment by all other methods is unsatisfactory.

In the endeavour to define the therapeutic field which should belong to diathermy the author will include in the following pages the maladies which rarely respond to other forms of treatment. For these diathermy is the treatment *par excellence*. There will also be included those maladies in which other forms of treatment (including surface-heating) are successful in *some* cases, not in others. In the latter diathermy is frequently successful. There will also be included certain maladies in which diathermy seems to procure satisfactory results more quickly than other methods of treatment.

The author has no intention of including in the field of diathermo-therapy the simple maladies which can be

successfully treated by simple methods. It is possible that diathermy might procure quicker results than epithermy in straightforward cases, but the new treatment is the work of the specialist and should be reserved for special diseases and special cases.

In including the diseases considered in the following pages the author writes almost entirely from his own experience, either in hospital or private practice where cases were sent only after trial of other forms of treatment.

Section I

Diathermy in the treatment of subnormal temperature and deficient physiological activity (hypothermia)

The clinical condition about to be described does not appear to have been recognised as a definite malady, but it will be frequently encountered if looked for. The fact that it is frequently accompanied by other maladies directs the attention of the patient to the latter, and although he may complain of general malaise and a feeling of continuous chilliness, he attributes these symptoms to some local malady such as neuritis, rheumatism, etc. When no local malady is present and no organic disease, he complains of his inability to bear the cold and longs for the advent of warm weather.

Symptoms such as loss of appetite and dislike for food, dyspepsia, inability to sleep, depression, headache are frequently present. Women are frequent sufferers and some are poorly nourished.

Since the feeling of chilliness is the commonest symptom and a subnormal temperature the commonest sign, the name "general hypothermia" is suggested in order to connote the clinical condition above described.

The patients may be regarded as the subjects of deficient physiological activity, especially of the processes concerned in the production of heat and the maintenance of the normal temperature. For cases of this kind diathermy is a rational

and successful form of treatment, in that it supplies the heat that the body cannot produce, thereby giving the thermogenetic mechanism a rest and enabling it in suitable cases to resume its normal activity.

When other maladies such as neuritis or fibrositis are present at the same time, their disappearance is not infrequently observed during a course of general diathermy and without local treatment. Cases, also, are seen in which local treatment is successful only after general diathermy.

The symptoms of "hypothermia" are frequently noted in old people, and a subnormal temperature is found. If there is no local or general malady they complain merely of their inability to keep warm during the winter months. General diathermy is no less gratefully received by them than by young patients. It is the treatment for old patients as well as cold patients.

It is a good plan, when undertaking the treatment of patients by physical methods, to inquire whether the symptoms above noted are present and measure the general temperature. If there are complaints of general chilliness and inability to keep warm, and particularly if the temperature is subnormal, a course of general diathermy should be commenced, and local treatment may be administered later if necessary.

Method of Application and Frequency of Treatment.—The method which the author usually adopts is to place the patient on a condenser couch, with a cylindrical electrode grasped by both hands. In the absence of a condenser couch the patient may recline on a sofa, and hold a cylindrical electrode in each hand. When possible, daily séances are held, each lasting from fifteen minutes to half an hour, until the oral temperature rises to normal, or 99° F. The temperature may be raised higher—to 100° F. if the patient loses the sensation of warmth before the next visit, and if there is no feeling of discomfort after the treatment. Occasionally there is a feeling of fatigue if a high temperature is attained. It is well to remember that a feeling of dizziness may be noted by the patient on getting off the couch after diathermy. In the author's experience this is not common, and—when it has occurred—short-lasting.

Results of Treatment.—Diathermy procures great benefit for the malady under consideration. The feeling of chilliness disappears. The patients lose their symptoms of lassitude, headache, dyspepsia, etc. They are able to sleep at night and a feeling of well-being is regained. Thin patients often gain in weight. As already mentioned, the symptoms of concomitant maladies may disappear without local treatment.

The results are long-lasting. A year or more elapses without return of symptoms. Some cases appear to have been permanently cured.

When the patient is the subject of chronic progressive disease the symptoms of continued chilliness do not respond so well to diathermy. The author has notes of a case of chronic Bright's disease in a gentleman of sixty who could never keep warm, summer or winter alike. This patient felt comfortable during the course of diathermy, but the relief was of short duration. Far different were the results obtained in this patient's sister, whose case was suitable for diathermy. The case is described below because the results appear to be permanent over a period of nearly eight years.

Case 1.—The patient, a lady of 56, single, of very small stature, thin and fragile, had always felt the cold of the winter months acutely when in England, and, before the Great War, had spent these months abroad. During the winter of 1918–19 she suffered greatly from the cold and could not keep warm away from the fire. Her appetite failed and she ate very little and became still thinner. At night the feeling of cold prevented sleep.

Treatment by general diathermy was commenced on January 23rd, 1919. On this day her oral temperature was 96·6° F. Seventeen applications were made during a period of two months. The improvement of the patient's condition was remarkable. Her symptoms disappeared soon after the commencement of the diathermy and she remained comfortable, and free from cold.

A short course of treatment was given in the summer of 1920, a third in October and November, 1921. In November and December, 1922, four applications were given. On each of these occasions the symptoms had returned, but in slight degree only. Since the last treatment (on December 1st, 1922) the patient has been in good health and has shown considerable bodily and mental agility.

The following table shows the gradual rise of temperature during a course of diathermy in another case. The temperature before and after the applications was taken, also that at 7 a.m. and that at 10 p.m. Those at 7 a.m. and 10 p.m.

were taken by the patient (who was accustomed to the work), and the same thermometer was used throughout. The figures represent the averages for each week.

Period of treatment and observation.	Average temperature at 7 a.m.	Average temperature before diathermy.	Average temperature just after diathermy.	Average temperature at 10 p.m.	No. of applications of diathermy.
February 4–10 . . .	—	95·4	97·7	—	5
February 11–17 . . .	96·2	96·5	98·3	96·7	5
February 18–24 . . .	96·9	97·16	98·76	96·85	5
February 25–March 1 .	96·7	97·3	98·8	96·9	4
March 9–19	97·1	97·2	98·76	97·37	5
March 20–25	97·3	—	—	97·3	—
March 27–April 1 . .	97·0	—	—	97·0	—
April 2–8	98	—	—	98·1	—

Case 2.—The patient in whom the temperatures noted above were taken was a lady of 40 and was sent to the writer for treatment of brachial neuritis. She complained, in addition, of general fatigue, cold (which kept her awake at night) and depression. These additional symptoms had been of much longer duration than the pain. General diathermy soon produced improvement of the patient's condition. The absence of the feeling of cold during the night was first noticed, and sleep was readily obtained. Appetite returned and fatigue disappeared. She gained three pounds in weight in seventeen days.

In this case the pain due to the neuritis did not disappear during general diathermy, but it was quickly abolished when local diathermy was given in addition. The patient wrote six months later to say that she felt perfectly well.

The results obtained in the next case show the benefit that may be derived from general diathermy even though the local malady may be incurable.

Case 3.—The patient, a girl of 19, was sent for treatment of a condition of "chilblain circulation" in her hands and feet. Her hands and wrists, feet and ankles were swollen, dusky blue and cold. Physical examination elsewhere showed nothing abnormal. She was thin, and complained of feeling always cold. In manner she was dull and morose. Diathermy was applied and the temperature of the whole body raised. This treatment had no effect on the swelling of the extremities, but the general health of the patient improved greatly. Her appetite increased and she gained weight, and colour reappeared in her cheeks. According to the account of her sister, with whom she was living, she became active and cheerful and worried no longer about her local condition.

The importance of the recognition of hypothermia in patients who are the subjects of other maladies is shown in the following two cases. Both were treated by general diathermy. In one the local malady—a painful scar—received no treatment. In the other—a case of severe neuralgia in the lower limbs—the latter parts were included in the diathermy, but the treatment was not localised to the nerve trunks.

Case 4.—The patient, a girl of 23, had undergone an operation three months previously for removal of her gall bladder. During convalescence she developed pain and tenderness in and around the scar. She was sent to the writer for treatment of the pain. She was thin and morose in appearance and complained of chilliness and depression—a condition which she said was always present when she spent the winter in England. She said that she could not bear the slightest pressure on the site of the operation and was positive that no treatment would do her any good. In these circumstances no local treatment was given. General diathermy was administered on the condenser couch. When the patient felt the sensation of cold disappearing and the development of warmth her expression changed. She remarked that she never felt warm since the beginning of autumn. (The treatment was commenced on November 12th, 1923.) During the course of the diathermy she became cheerful, and took an interest in her occupations. The scar retained some tenderness on pressure but ceased to be a source of trouble.

Case 5.—The patient, a gentleman of 39, complained of severe pain in his lower limbs. Seven weeks previously he had suffered from an attack of tonsillitis. He said that he had had much pain in his throat and considerable swelling, but no rise of temperature. As the tonsillitis subsided pain developed in his waist and then in his hands. It lasted ten days and then appeared in his lower limbs, where it persisted. It became very severe. It occurred in bouts, usually between 1 and 2 p.m. and during the night. Sleep was impossible, and the patient said that he paced up and down his room during the night until nearly morning, when he fell asleep from exhaustion. By reason of his history, that he had returned (in January, 1923) to England after ten years' residence in India and had felt the cold of the English winter acutely, it was decided to administer general diathermy. The first treatment was given on November 14th, 1923. Electrodes were applied to the soles and the current was directed along the lower extremities for forty-five minutes. The same night the patient slept continuously and was almost free from pain when he came for his next treatment. Three treatments alone were given because the patient had to leave London. His pain had not disappeared entirely before leaving, but was only slight. A communication received at a later date showed that the patient had resumed his occupation, the pain being only slight and occasional.

Section II

DISEASES OF THE URO-GENITAL ORGANS IN WOMEN

By means of the diathermy current it is possible to raise the temperature of the pelvic organs in their entirety and obtain the therapeutic effects of heat in deep-lying structures and tissues that are inaccessible to heat derived from external sources. The power of heat to relieve pain and spasm, to accelerate the circulation and aid the tissues in their efforts to free themselves from infection, can therefore be utilised in the treatment of suitable diseases of the urethra, the uterus and its appendages, and the pelvic supporting tissues.

During the past five years the treatment of women's diseases by diathermy has formed an increasing portion of the work of the Electrical Department of St. Bartholomew's Hospital, and the value of the treatment has been ascertained in cases which had resisted other forms of therapy. The results of a somewhat lengthy experience have shown that diathermy is of the utmost value in the treatment of the following diseases: (1) gonococcal urethritis; (2) endocervicitis and endometritis, due to the gonococcus or other organisms; (2) salpingitis; (4) vulvo-vaginitis in children; (5) erosion of the cervix; (6) some forms of dysmenorrhœa; (7) some forms of metrorrhagia; (8) chronic parametritis and perimetritis; (9) symptoms accompanying the climacteric.

Method of applying Diathermy to Urethra and Uterus.

Various electrodes and methods of application were devised by the author and his co-worker, Dr. Robinson, and subjected to trial during their investigation of the treatment of the female pelvic organs by diathermy. The most satisfactory and exact are the following:

The *urethral electrode* is shown in Fig. 45. It consists of a thin-walled metal tube $\frac{3}{16}$ inch in diameter. One end is closed and rounded; $1\frac{1}{2}$ inches from this end an ebonite disc is secured. Beyond this disc the wall of the tube is

absent in part so as to expose the scale of a thermometer in the tube. A terminal is attached to the open end of the tube.

Fig. 45.—Electrode for applying diathermy to female urethra.

The *electrode for the cervix uteri* (Fig. 46) is a metal rod made of a pliable tin-lead alloy. Both ends are graduated. $\frac{3}{4}$ inch from one end the rod is bent to an obtuse angle to suit the degree of version and flexure of the uterus and enable

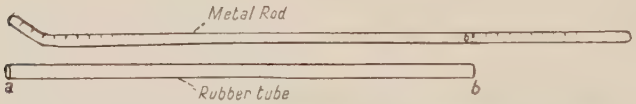


Fig. 46.—Electrode for application of diathermy to uterus.

easy insertion into the canal of the cervix. A thick-walled rubber tube slides easily over the rod. It is 12 inches long.

The *electrode for the entire uterus* is similar to that just described but is bent to the same curvature as a uterine sound.

The *directing electrode* which completes the body circuit is a belt of sheet lead $3\frac{1}{2}$ inches wide and four feet long. It is placed around the pelvis, and the overlapping ends are passed through a stout wire loop and bent back so that the belt makes firm and even contact with the skin. The loop resembles a large safety-pin. A terminal is attached to it (Fig. 47).

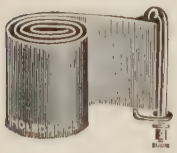


Fig. 47.—Metal belt for use as directing electrode.

Insertion of electrodes and regulation of current.—The patient lies on her back and the urethral electrode is introduced. That portion which lies between the ebonite disc and the closed end is inserted into the channel. Its outer end is supported by the stand shown in Fig. 48. This stand is placed between the slightly abducted thighs, and the rod to which the electrode is secured can be adjusted in any direction

and maintain the electrode firmly and immovably in position. The cable from one of the terminals of the diathermy machine is attached to a binding screw on the stand. The belt electrode is placed around the pelvis in contact with the bare skin. The other cable is attached to the terminal on the wire loop.

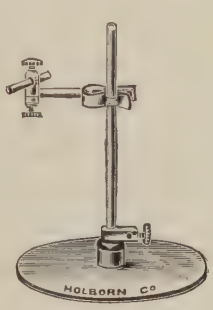


Fig. 48.—Stand for support of urethral or cervical electrode.

The current is now started and gradually increased. The patient feels a sensation of heat in the urethra. As the current is increased she feels the heat increase. Ultimately a point is reached at which she feels the sensation of heat replaced by one of pain. The current should then be reduced until the pain just disappears and heat alone is felt. The reading of the amperemeter should then be accurately noted and the current allowed to continue for ten minutes. It is then switched off. This completes the first treatment of the urethra.

It is important that the current should be increased *slowly*. The tissues do not at once attain the maximum temperature possible for each strength of current, and if the latter is increased *quickly* until pain is felt it will have to be reduced repeatedly before it ceases to cause pain. If the current is quickly increased there is a risk of overheating the urethra.

The *critical* temperature, that at which the sensation of heat first changes to one of pain, has been found, by thermometric measurements, to lie between 114° and 115° F. At the first treatment the patient is usually nervous and may complain of pain before 114° is reached, but when her confidence and co-operation are gained it is found that the critical temperature is nearer 115° than 114°. A temperature of 114° will not damage the urethra. The author and his co-workers prefer to rely on the sensations of the patient rather than on thermometric measurements, and to use a current that will cause the maximum sensation of heat without pain, whatever the thermometer may indicate. During the evolution of the above-described technique,

thermometers were not used and no burns were produced or any reaction sufficient to cause pain during micturition.

Immediately after each treatment of the urethra the cervix uteri is subjected to diathermy. The belt electrode is allowed to remain in position; the urethral electrode is removed and a speculum is passed *per vaginam*. A Brewer bivalve speculum is preferred. The electrode for the cervix is passed into the canal of the latter. The rubber tube is placed over it and pushed along till its end is in contact with the cervix. The length of insertion of the electrode is measured by noting the position of the other end of the rubber tube in relation to the graduation on the external end of the electrode. The latter is supported on the stand. The current is now started and increased to the strength that will heat the tissues in contact with the electrode to the same temperature as the urethra. Now the cervix cannot perceive the sensations of heat or pain, but the current that will heat it to the required value can be ascertained by a simple calculation. The length of insertion of the urethral electrode was $1\frac{1}{2}$ inches, *i.e.* the length of the urethra in adult females. Now suppose that the length of insertion of the cervical electrode is half this—$\frac{3}{4}$ inch being the length of the canal of the cervix in adult females. If both electrodes have the same diameter it follows that the area of tissue in contact with the cervical electrode is half the area that was in contact with the urethral electrode. This being the case, the current used for the cervix should be half that used for the urethra. The current will then have the same *density* in the cervix as in the urethra, and the tissues in contact with the electrode will, theoretically, be heated to the same temperature. By means of an electrode which was specially designed for use with a thermometer (Fig. 49) it has been found that such is the case.

A cervical electrode enclosing a thermometer is not a handy instrument for routine use. It is inflexible and the thermometer is fragile and costly. The simple electrode is more useful and serviceable, and when it is employed the current which will produce the correct temperature in the cervix can be easily calculated.

When the cervix of nulliparæ is treated the canal does

not usually admit an electrode $\frac{3}{16}$ inch in diameter. One of $\frac{1}{8}$ inch in diameter should be used and the current diminished in proportion.

When the internal os is patent the curvature of the electrode should be modified and the instrument passed as far as the fundus of the uterus. The length of insertion should be noted and the current increased in proportion.

FIG. 49.—Electrode for applying diathermy to cervix uteri (electrode contains a thermometer).

At each session the treatment of the cervix should *always* be preceded by treatment of the urethra, whether the latter is normal or not. The current which produces the correct temperature of the urethra is not the same from day to day, because the resistance of those parts of the body that are in the circuit is not always the same. On one day a current of 1·2 amperes may be required; on another day 1·4 amperes may be necessary; on a third day 1·3 amperes may be required to obtain the correct temperature.

Two sessions should be held weekly. The number of sessions depend on the nature of the infection and the local conditions.

FIG. 50.—Electrode for applying diathermy to tubes and ovaries.

Application of Diathermy to the Tubes and Ovaries.—Active Electrode. This is shown in Fig. 50. It consists of an ebonite stem 1 inch in diameter. To one end is secured a metal end-piece which is in electrical connection with a terminal at the other end. The total length is 8 inches. The body circuit is completed by means of a belt electrode, identical with that described above, placed around the *waist*.

Application of Electrodes and Regulation of Current.— The active electrode is anointed with soap and water or some grease-free lubricant and passed *per vaginam* until the metal end is in contact with the cervix uteri. It is maintained in position by means of the stand already described. The belt electrode is secured around the waist. After connecting the electrodes to the diathermy machine the current is started. It is increased until the temperature of the parts in contact with the inner end of the electrode reaches 105° or 106° F. This temperature can be ascertained by means of a thermometer passed by the side of the electrode with its bulb in the posterior *fornix vaginæ*. The current is allowed to pass for twenty minutes. The sessions are repeated twice weekly.

When the electrodes are applied in the situation just mentioned, the lines of oscillation of the current radiate outwards from the active electrode and obliquely upwards to the belt electrode. Their relation to the active electrode is that of the conical part of a glass funnel to the stem. The stem corresponds to the active electrode and the conical portion to the lines of the current. The rim of the funnel corresponds to the belt electrode. The uterus and its adnexa would lie a short distance from the narrow end of the funnel cone.

In this method of applying diathermy the temperature attains its maximum value in the cervix and upper end of the vagina. In the tubes and ovaries it is lower, but the degree which it attains cannot be measured. Although the parts in contact with the metal end of the active electrode can be heated to 114° F. without damage, it has been found that the diseases of the tubes and ovaries suitable for treatment by diathermy respond just as well, not to say better, when the temperature in the posterior fornix rises no higher than 106°.

This form of treatment may be termed "general pelvic diathermy" to distinguish it from "urethral diathermy" and "cervical or uterine diathermy." In the two last mentioned a high degree of heat is concentrated in the parts requiring treatment. In "pelvic diathermy" the heat is not concentrated in the tubes or ovaries and the temperature does not attain a high degree in these organs.

Application of Diathermy to the Uterus and its Appendages by the Rectal Route.—When it is undesirable to pass an electrode or speculum *per vaginam* the uterus and its adnexa can be subjected to diathermy by the rectal route.

Electrodes.—The *active* electrode is shown in Fig. 51. It consists of a thin-walled brass tube, $4\frac{1}{2}$ inches long and half an inch in diameter. One end is rounded and closed; the other end is open. Two brass rods $\frac{1}{16}$ inch thick and 14 inches long are attached to the open end. Each rod is hinged midway between its extremities so that it can be bent. Over each rod is placed a rubber tube $\frac{3}{16}$ inch in

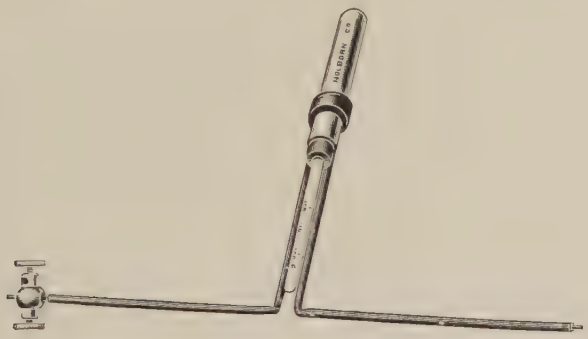


Fig. 51.—Electrode for application of diathermy to uterus by rectal route. This electrode is also used for applying diathermy to the prostate and vesicles by the same route.

internal diameter. The tube covers the rod except for an inch at its free end. To the free end of one of the rods is attached a terminal. A perforated rubber cork fits into the end of the tube. A thermometer is passed through the perforation so that its bulb lies near the closed end of the tube. The cork makes air-tight connection with the thermometer and tube. An ebonite washer, $\frac{3}{8}$ inch thick, is secured in position on the tube 4 inches from its closed end. That portion of the tube between the closed end and the washer is placed in the rectum.

The directing electrode is a metal belt identical with that already described.

Application of Electrodes and Regulation of Current.—The patient lies on her left side and the electrode, lubricated

with soap and water or boracic ointment, is passed into the rectum for 4 inches. She now lies on her back and draws up her thighs a little. The rubber-covered metal rods are not bent to a right angle. The patient now straightens her lower limbs and lets them rest on the couch. The bent portions of the rods thus lie under the thighs, the latter pressing them on to the couch. The electrode is therefore kept in position and prevented from moving. In this position the electrode acts as a lever, the anus being the fulcrum. The short arm of the lever (*i.e.* the portion of the electrode within the rectum) presses the anterior wall of the rectum and the uterus towards the anterior abdominal wall.

The body circuit is completed by means of the belt electrode placed around the pelvis.

The current is now started and slowly increased. The patient feels the sensation of warmth within the rectum. The warmth increases and eventually the patient complains of pain in the rectum. Pain is first felt at a temperature of 112° F. In some patients it has been found possible to reach 114° before pain is felt, but the critical temperature is more difficult to ascertain with the exactness that is possible in the urethra. The current is reduced until pain just disappears. It is allowed to pass for twenty minutes. The sessions are held twice weekly.

The uterus does not attain as high a temperature as the rectum because it lies further away from the active electrode. It may be assumed that the temperature within the uterus is four degrees lower than that of the rectum.[1]

Although the uterus and its appendages lie mainly in front of the rectal electrode it is an advantage to place the belt electrode completely around the pelvis. It is true that some of the current will pass posteriorly and not traverse the uterus. But this portion of the current will heat the pelvic tissues behind the uterus, and it is better for the heated

[1] Some observations were made by Dr. C. A. Robinson in order to ascertain the temperature which could be reached in the cervix during application of diathermy by the rectal route. A thermometer was placed with its bulb in the canal of the cervix of a multipara and diathermy administered by the rectal route. It was found that the intra-cervical temperature was 108° F. when that in the rectum was 112° F.

uterus to lie in heated surroundings than to have the parts behind it at normal temperature.

Application of Diathermy to the Pelvic Organs of Infants and Children.—The pelvic organs of infants and children have been subjected to diathermy by the author and his co-workers in cases of infection by the gonococcus or other organisms. Excellent results have been obtained and no harm has resulted. The diathermy was administered by the rectal route and the electrodes were similar to those just described.

The rectal electrode has a smaller calibre, being $\frac{3}{8}$ inch in diameter. When the vagina ceases to be inflamed and tender the electrode should be introduced into that passage. A temperature not higher than 106° F. should be produced. The duration of each treatment should be twenty minutes and the frequency of its administration twice weekly. The exercise of patience and other good qualities is necessary in the treatment of young patients. It is a good plan, at the first visit, merely to apply the belt electrode and let the patient hear the machine in operation. At the second visit the rectal electrode may also be inserted, but no current passed until the third visit.

Treatment and Results.

Gonococcal Urethritis and Endocervicitis.—For these diseases diathermy is an admirable form of treatment. Pain and irritation during micturition, if present, disappear. Redness and swelling at the external urinary meatus subside. All signs of inflammation disappear from the cervix also and the part regains its normal appearance. Discharge seen emerging from the os loses its green or brown colour and then disappears. Gonococci are no longer found in the secretion obtained by tapping the cervix nor are they recovered from the urethra. In all the cases which have been kept under observation, some for a year or more, the results have been permanent.

The use of diathermy for the elimination of gonococci from the tissues is a rational procedure. In the first place, the temperature which will kill the organisms is not high

enough to damage the tissues. Secondly, the power of the tissues to eradicate infection is increased by heat. In the third place, the heat generated by the diathermy current is not localised to the surface but distributed throughout the infected tissues.

The action of diathermy on infection is both *direct* and *indirect*. In the former the vitality of the organisms is lowered or destroyed; in the latter the powers of the tissues to eliminate them is increased. It is highly probable that the *indirect* action is more potent than the direct. Organisms with high lethal temperatures can be destroyed by diathermy without exceeding a temperature that will harm the tissues. Further, it is possible to terminate gonococcal infection by heating the tissues to temperatures which are lower, and for times which are shorter, than those found necessary in experiments on cultures.

It is inadvisable to use the word "cure" when speaking of gonococcal infection, because there is no known test for the absence of these organisms *from the tissues*. All evidence, however, favours the conclusion that diathermy effects a cure of gonococcal infection of the cervix and urethra in women. In these diseases diathermy *appears* to be a specific. Two patients married after the treatment and no subsequent history of transfer of infection was received. One wrote nine months after marriage and the other five years after.

These results are obtained after other methods have been tried and proved unsuccessful. All the cases originally treated by the author and his co-workers by diathermy (in order to assess the value of the new treatment) had been previously treated by other methods without success. The same is true of most of the cases that have been treated since.

A striking demonstration of the therapeutic value of diathermy in gonococcal endocervicitis is furnished by the disappearance of metastatic infection. Reference to this will be found in the sections dealing with the treatment of the joints and supporting tissues.

In the author's experience diathermy is successful however long the duration of the disease before the treatment. It is equally successful in early cases. The author has

no hesitation in applying diathermy however early the case may be.

It is hardly necessary to mention that the patient should not be exposed to risk of re-infection during or after the course of treatment. Diathermy confers no immunity. In married patients it is advisable to make appropriate inquiries. It will be necessary, unless adequate precautions are adopted, to treat the husband as well.

Whenever possible the cervix should be treated by the vaginal route and the electrode placed in its canal as described. In adults the urethra can be treated by means of the urethral electrode. In children and infants the treatment must be administered via the rectum or, when pain and tenderness have subsided from the vagina, via that passage.

The number of applications necessary in gonococcal urethritis and endocervicitis is from three to five, seldom more. As already stated, each part is treated for ten minutes at each session and the treatment is repeated twice weekly. When administered by the rectal route duration of each treatment should be twenty minutes. Six to eight sessions are required.

Endocervicitis due to other Organisms.—In cases of infection of the cervix by organisms other than gonococci the results of treatment by diathermy are, in the experience of the author, no less satisfactory. The cervix regains its normal appearance; symptoms, such as pain in the sacrum, disappear, and the discharge from the os is replaced by clear secretion. The patient loses her sallow "muddy" complexion and her general health is greatly improved.

There is additional evidence of the therapeutic value of diathermy in non-gonococcal infection of the cervix. If the disease is complicated by the presence of arthritis or fibrositis the application of the treatment *to the cervix* is followed, in the larger proportion of cases, by cure or arrest of the complication. Up to the present time this has been the result in 70 per cent. of the cases treated by the author and his co-workers. In the successful cases it may be assumed that the cervix was the primary focus of infection, and the joints and fibrous tissues the sites of metastatic infection.

The organisms most usually found are coliform bacilli, diphtheroid bacilli and the streptococcus fæcalis. The last-mentioned has a high lethal temperature. Dr. Mervyn Gordon found that it was necessary to expose cultures of this organism to 50° C. for four hours to destroy them. It is evident, therefore, that the action of diathermy in heating the cervix to 114° F. (45·5° C.) for ten minutes is not a *direct one on the organisms themselves.* The destruction of the latter must be due to the action of the heat on the infected tissues.

The bacteriology of the infected cervix before and after diathermy has not been fully investigated. In one case, however, the uterus was removed two months after the cervix had been subjected to a course of diathermy. It was thoroughly examined for the presence of organisms but was found to be sterile. The streptococcus hæmolyticus was the original infecting organism.

Infective Endometritis.—When the electrode passes easily into the body of the uterus through a patent internal os it is assumed that the body as well as the neck of the uterus is infected. Diathermy is applied according to the technique described and the results are as good as those obtained in endocervicitis.

Salpingitis.—Many successful results have been obtained in the author's clinic in the treatment of salpingitis by diathermy. Some of these were gonococcal. Others were in women who had developed endocervicitis after confinement. In the latter there was no evidence of gonococcal infection. Most of the cases were chronic and showed little or no rise of temperature. A few were subacute and had a temperature of 102° or 103° F.

The treatment of salpingitis should be commenced by giving general pelvic diathermy in the manner already described. After three or four applications, given bi-weekly, the treatment of the infected cervix should be commenced. It should be continued until evidence of endocervicitis is negative. If endometritis is also present, diathermy should be applied to the entire uterus.

The treatment of the cervix uteri is more important than that of the tubes because it removes the source of the in-

fection. If, however, they are treated *before* the tubes the patient is likely to develop pelvic pain which may persist for a day or even a week. For this reason the treatment of the tubes should precede that of the uterus.

Vulvo-vaginitis in Children.—Cases of this disease in children respond well to diathermy whether gonococci are found or not. Dr. C. A. Robinson treated two cases in children who were 2½ years old. Diphtheroid bacilli were found. The discharge disappeared and the parts regained their normal appearance. The youngest patient in whom gonococci were found was a girl of five. After diathermy the discharge and signs of inflammation disappeared. A bacteriological examination was made by Mr. Johnston Abrahams, but no gonococci were discovered.

A case in which the therapeutic power of diathermy was well shown was that of a young girl, aged six, who was admitted to St. Bartholomew's Hospital under the care of Mr. MacAdam Eccles. She suffered from acute abdominal pain and her temperature was raised. The abdomen was very tender. Vulvo-vaginitis was present and gonococci were discovered. Treatment by vaginal irrigation had no effect on the abdomen, and after it was commenced arthritis developed in one of the wrists. The patient was then sent to the Electrical Department. Diathermy was applied by the rectal route. Pain and tenderness disappeared from the abdomen and wrist and the temperature fell to normal. The discharge disappeared. As soon as the vaginal tenderness disappeared diathermy was applied by the vaginal route. The patient made a complete recovery.

In the treatment of the vulvitis the action of the diathermy is considerably accelerated by local application of ultra-violet rays. The latter cannot, however, replace diathermy in the treatment of the deeper parts.

Erosion of the Cervix.—" Erosion " is caused by the constant passage of discharge over the vaginal aspect of the cervix. The normal epithelium of the latter disappears in part, leaving little islands of stratified epithelium. Some of the gland ducts open on the " eroded " area between these islets. Treatment, therefore, should be directed on the infected glands, not on the " eroded " area. Diathermy

terminates the infection of the glands and the "erosion" disappears. If the case is early it will disappear in the interval between two successive periods. "Erosion" of long duration requires treatment for a longer time. Up to the present time no case has failed to respond to diathermy in the Electrical Department at St. Bartholomew's Hospital. In the severest and most resistant of the cases the "erosion" gradually subsided and eventually disappeared in ten months. Treatment was given twice weekly in the intermenstrual intervals. This case was sent by Dr. Wilfrid Shaw, who had tried other forms of treatment without success.

Diathermy should be administered in the manner already described for infective endocervicitis, and the frequency of the treatment and the duration of each application should be the same.

Dysmenorrhœa.—During the past three years a considerable number of cases of dysmenorrhœa have been treated by diathermy in the Electrical Department of St. Bartholomew's Hospital. Uniformly excellent results have been obtained in cases in which the dysmenorrhœa is associated with inflammation of the uterus and its adnexa or the pelvic supporting tissues. The inflammation is probably the cause of the dysmenorrhœa, and its successful treatment is followed by cure of the painful menstruation. This "inflammatory" type of dysmenorrhœa should therefore be treated by applying diathermy to the pelvic genitalia or supporting tissues. Endocervicitis, endometritis, salpingitis, öophoritis and pelvic cellulitis should be treated by the methods already described, and the frequency and duration of the applications should be the same.

When dysmenorrhœa is present in patients who present no organic disease or inflammation of the pelvic organs it should be treated by general pelvic diathermy in the way described on p. 152. The duration of each application should be twenty minutes, and the frequency twice weekly.

This may be termed the "spasmodic" form of dysmenorrhœa. In some of the cases the cervix uteri is conical in form and the uterus may be of the "infantile" type. Spasmodic dysmenorrhœa is treated by the writer and his coworkers by applying general pelvic diathermy, either by the

vaginal or the rectal route. Some apparent cures have been obtained, but success has not been procured with the same degree of uniformity as in the "inflammatory" type. It is uncertain whether the frequency of the treatment and the duration of the course have been correctly ascertained. Up to the present time the treatment has been given twice weekly in the intermenstrual periods, each application lasting twenty minutes. In a few cases complete and lasting relief was obtained. In the others the relief was incomplete and the continuation of the diathermy did not procure further benefit. In some cases the pain appeared to regain its original severity. It was therefore decided to try the effect of continuing the diathermy over a prolonged period. Two severe cases were selected. In these the pain was severe enough to compel the patients to stay in bed for the first two or three days of the periods, and vomiting occurred. Diathermy was given twice weekly. After some initial improvement both patients relapsed. The treatment was continued. Some improvement took place at a later date, and after the lapse of five months the patients were not suffering more than the customary degree of discomfort and the vomiting ceased. It is too soon yet to say whether these results are permanent. They are, however, encouraging, in view of the severity of the cases. Further investigation of the effects of diathermy in spasmodic dysmenorrhœa is now being made and the results will be reported later.

A few of the uncommon cases in which pain is felt, not *during* the loss, but midway in the intermenstrual periods, have been treated by the author and his co-workers. Diathermy was successful in some, not in others. Ovulation occurs midway in the intermenstrual period. In rare cases hæmorrhage occurs in the ovaries when ovulation takes place. It does not appear likely that diathermy could prevent this hæmorrhage. Pain may also occur during ovulation if there are adhesions around the Fallopian tubes and a disturbance of the peristaltic action of the latter. Diathermy may relieve irregular peristalsis. It is suggested that the cases in which diathermy was successful were of the last-mentioned type.

Amenorrhœa.—Some cases of amenorrhœa in patients

possessing the so-called "infantile uterus" have been treated in the author's clinic by intrapelvic diathermy. After a few applications a "show" was noticed. Continuation of the treatment was followed by monthly losses, which, however, were scanty in amount. In no case was a normal menstrual loss obtained.

When amenorrhœa accompanies diseases of organs other than the pelvic genitalia its treatment will be determined by the nature of the disease with which it is associated. Some forms of arthritis in women seem to be associated with disturbance of the ovarian functions. In young women arthritis may develop at the period when menstruation is being established. It may also develop during the climacteric. At both periods it is accompanied by amenorrhœa. The application of diathermy to the interior of the pelvis is followed, in many cases, by disappearance or arrest of the arthritis.[1] In young women the menstrual losses are resumed. In older women in whom the onset of the climacteric is unduly premature there may be a temporary resumption of menstruation. In one of the cases treated in the Electrical Department of St. Bartholomew's Hospital there was a temporary return of menstruation after amenorrhœa for ten years. In another case it reappeared after cessation for $3\frac{1}{2}$ years.

Diathermy has a potent influence on the functions of the ovaries and should receive an extended trial, especially in cases of amenorrhœa in patients presenting no obvious fault of development and no constitutional malady.

Metrorrhagia.—The metrorrhagia which sometimes occurs during the climacteric responds admirably to pelvic diathermy. Speaking from the experience gained in the Electrical Department of St. Bartholomew's Hospital the treatment is always successful. Even if there are severe floodings the bleeding is quickly stopped. In some cases there may be one or two more normal periods before permanent cessation of menstruation. In others there is no return of menstruation or bleeding after the metrorrhagia has been terminated by diathermy.

A case which shows the potency of diathermy in metro-

[1] Reference to this subject will be found on p. 176.

rrhagia occurred in the author's private practice. The patient, a lady of 38, had suffered from severe bleeding for six weeks. She showed an extreme degree of pallor. The uterus was enlarged and a diagnosis of a submucous myoma had been made by a gynæcological surgeon, and hysterectomy advised. The patient implored her medical adviser to ascertain whether any alternative treatment could be tried. For this reason a trial of pelvic diathermy was made, but without much expectation of success. The bleeding soon stopped, however, and after an interval of three weeks normal menstruation was resumed. The treatment was continued, and ultimately there was no palpable enlargement of the uterus. At the present time (five months after the commencement of the treatment) the patient is perfectly well. Menstruation has been regular and the loss normal in amount.

By reason of these results it is questionable whether the diagnosis of myoma was correct. The pelvic swelling was probably inflammatory.

Parametritis and Perimetritis.—The pain and discomfort due to chronic inflammation of the pelvic supporting tissues can be remedied by pelvic diathermy. A considerable number of cases have been treated by the author and his co-workers and good results were always obtained.

The treatment should be commenced by administering diathermy to the interior of the pelvis, using the vaginal and belt electrodes already described. When the pain is relieved the cervix uteri should be submitted to a course of the same treatment.

Symptoms of the Climacteric.—The treatment of a number of cases of arthritis occurring at the climacteric by means of pelvic diathermy has afforded the opportunity of studying the effect of the same treatment on the vaso-motor and psychic symptoms which occur at this period. It was found that these symptoms were lessened in severity or disappeared altogether during the course of treatment. It cannot be stated at present whether the results are permanent or not, but there is no doubt that patients who were treated derived benefit during the course of the diathermy. One patient who had been the subject of cataleptic seizures was free from them while she was under treatment.

Section III

DISEASES OF THE URO-GENITAL ORGANS IN MEN

In the treatment of certain infective diseases of the testis and epididymis, and of the prostate gland and seminal vesicles, diathermy is highly successful, not only in cases which have received no previous treatment but also in those which have resisted other forms of therapy. Most experience has been gained in the treatment of gonococcal infection. In a few cases the infecting organisms were pyogenic cocci or coliform bacilli. In some the infecting organisms were not ascertained.

Application of Diathermy to the Prostate and Vesicles.

For the application of diathermy to the prostate and vesicles the author uses a method identical with that described on p. 153 for administering the same treatment to the uterus by the rectal route. The rectal electrode (Fig. 51, p. 153) is introduced 3 inches, and the belt electrode (Fig. 47, p. 148) is secured around the pelvis. The current is slowly increased. The sensation of heat is felt to increase, and ultimately the patient feels discomfort. Some patients complain of a sensation of pain; others say that they feel an uncomfortable ache. As soon as any discomfort is felt the current should be reduced until it just disappears. Some patients feel pain or an unpleasant ache at a temperature of 110° F. Others are able to tolerate a temperature of 111° or 112° without discomfort. The author has never been able to increase the temperature beyond 113° without causing pain. The prostate gland, it will be remembered, is enclosed within a capsule, and if it swells under the influence of the heat the patient is likely to feel pain in the inflamed gland. It is therefore difficult to distinguish the pain caused by undue heating of the rectal mucous membrane from that due to swelling and compression of the gland within its capsule. But, whatever the cause of the pain or discomfort may be, it is advisable to reduce the current as soon as any sensation, other than heat, is felt by the patient.

The temperature recorded by the thermometer is not that of the prostate or vesicles, but that of the rectal mucous membrane in contact with the electrode. The temperature attained in the vesicles cannot be recorded, but there is reason to believe that the secreting glands of the prostate reach a temperature four or five degrees below that recorded in the rectum. The situation of the prostate in relation to the rectal electrode is the same as that of the cervix uteri to an electrode similarly placed. The temperature in the cervical canal has been measured when diathermy was applied to the cervix by the rectal route and found to be about four degrees below that reached in the rectum. (See footnote, p. 154.)

It must not be assumed that the higher the temperature of the rectum, prostate and vesicles (consistent with safety) the better will be the results. In the experience of the author the results obtained when the rectal temperature is 106° or 107° are as good as those obtained when it reaches 110° or higher. When commencing the treatment of a case it is a good plan to obtain an intrarectal temperature no higher than 105°. At the next visit the temperature may be raised a degree higher. As soon as the case begins to derive benefit there is no need to obtain higher temperatures. It is only in cases which are persistent in their refusal to respond to degrees of 106° or 107° that higher temperatures should be obtained.

Each application of diathermy to the prostate and vesicles should last for twenty minutes. The treatment should be repeated twice weekly.

Application of Diathermy to Testis and Epididymis.

Two electrodes are required. One of these is the rectal electrode already described. The other is shown in Fig. 52. It is made of thin sheet lead. It is 4 inches long and 3 inches wide. It is cut to the shape shown in the figure. A terminal is attached. This is the scrotal electrode.

The rectal electrode is first introduced and secured in position in the manner already described. The patient then lies on his back with his thighs together and his scrotum

supported on a pad covered with waterproof. Strips of lint, wrung out of hot salt solution—the latter being not less than 10 per cent. in strength -are applied to the scrotum so as to envelop it completely and form a pack $\frac{1}{4}$ inch thick. The lead sheet is now applied to the pack and bent so as to cover it and maintain its position with light and even pressure.

The current is started, and increased slowly until the patient perceives a sensation of warmth in the region of the neck of the scrotum. Its strength should be sufficient to produce comfortable warmth in the scrotum and rectum without pain in either part. The current should be passed for twenty minutes.

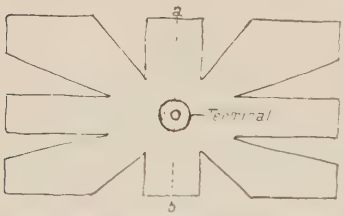


FIG. 52.—Electrode for applying diathermy to testis and epididymis.

By this method diathermy is administered, not only to the testis, epididymis and that part of the vas deferens which lies in the scrotum, but also the prostates, vesicles, posterior urethra and the parts which are in close relation to them. The inclusion of the prostate and vesicles is of the highest importance because they constitute the primary focus (or foci) from which a secondary infection may be disseminated among distant parts. They are the gates to metastasis. For this reason the author always includes the prostate and vesicles in the treatment of infection (more especially gonococcal) of the testis, epididymis and urethra by diathermy. If metastasis has occurred the treatment of the prostate and epididymis is *essential*. If there is no metastasis the inclusion of these parts is almost certain to prevent it. Diathermy keeps the "watch on the prostate and vesicles."

Application of Diathermy to the Urethra.

The application of diathermy to the urethra in a manner that will secure uniform heating of all portions is a difficult if not impossible task. The posterior portion can be heated,

say, to 107° by the rectal route. The penile portion can, by local application, be heated to 114°. The remainder can also be heated to some degree. But whether the different portions are heated separately or simultaneously it is doubtful whether the entire channel can be raised to a uniform temperature. If the urethra is not evenly heated to a sufficient temperature the gonococci will survive in the parts that are inadequately heated.

The author is of the opinion that diathermy alone cannot free the anterior urethra, or those parts which lie outside the pelvis, from gonococci. It might assist other methods of treatment, but alone it has not the power. It is not generally known that the temperature of the anterior urethra, or at any rate the terminal two inches of the channel, is *subnormal*. Dr. C. A. Robinson investigated this subject in 1923 and found that the temperature of the terminal two inches averaged 93° F. If a clinical thermometer is introduced into the anterior two inches of a subject whose temperature is normal, the mercury thread will not rise to the lowest limit of graduation, *viz.* 95°.

Now the most favourable range of temperature for the growth of gonococci in the tissues is from 93° to 98° F. The urethra presents, therefore, a temperature suitable for vigorous growth of the organisms. The temperature of the female urethra, on the other hand, averages 99·2° F. This is the temperature of the parts within the pelvis. It is a little above the higher limit of the range most favourable for the growth of the gonococcus. These facts doubtless explain why gonococcal infection of the urethra is more severe in the male than in the female, and why diathermy, so successful in the treatment of the parts *within the pelvis*, is not of great value in cases of anterior urethritis. It is true that diathermy has produced apparent cures in a few early cases. But these are exceptional. In one early case Dr. Robinson subjected the anterior urethra to diathermy and maintained a temperature of 114° F. for an hour, but could not free the part from gonococci.

Methods of applying diathermy to the male urethra will be described at the end of the present section.

Application of Diathermy to the Vas Deferens.

That part of the vas which lies in the scrotum is included in the treatment when diathermy is applied to the testis and epididymis. Occasionally there is an inflammatory swelling in the region of the inguinal canal. This is apparently due to inflammation of the vas. When this swelling is found it should be subjected to diathermy by way of a plate electrode large enough to cover it. The treatment should be given after diathermy is applied to the contents of the scrotum, the rectal electrode remaining in position.

Results of Treatment.

Gonococcal Prostatitis and Vesiculitis.—Diathermy is of great value in the treatment of these diseases. Its therapeutic powers are well seen in the effects which it can produce in cases which have resisted treatment by other methods. It is in the treatment of cases of this kind that the author has obtained most experience. These cases had already been freed from infection of the anterior urethra, but prostatitis and vesiculitis, together or singly, persisted, although treatment by massage or vaccines had been tried. Gonococci were found in the discharge or in the fluid obtained by massage of the prostate. The application of diathermy then produced the following results. Discharge, if present, disappeared. Symptoms, such as pain in the perinæum, subsided. Gonococci were no longer found in the fluid obtained by massage of the prostate. In three cases a provocative dose of gonococcal vaccine was injected but no organisms were recovered.

Additional evidence of the value of diathermy in the treatment of gonococcal infection of the prostate and vesicles is seen in cases in which there is a complicating arthritis or fibrositis. The inflammation of the joints or fibrous tissues can be brought to an end by applying diathermy to the prostate and vesicles only.

Diathermy does not appear to be able to abolish the gleet which frequently persists after treatment of the prostate. The treatment was continued in a few cases

after all evidence of gonococcal infection had disappeared, but the gleet persisted. In one case the patient wrote to say that it disappeared six months after completing the course of diathermy.

As stated above, the major number of cases of gonococcal prostatitis and vesiculitis which have been treated by the author had been previously freed from anterior urethritis by the customary methods. If infection persists in the anterior urethra the application of diathermy to the prostate and vesicles should be commenced, but the course of treatment should be prolonged until the anterior urethritis has been brought to an end by appropriate treatment. The prostate and vesicles are likely to be infected afresh if their treatment by diathermy is concluded before the anterior urethra is free from gonococci. The anterior urethra may be treated by the customary methods. It may be treated by diathermy (see p. 172 for description of methods).

Although, in the author's experience, anterior urethritis can seldom be brought to an end more quickly by diathermy than by other methods, the advantage attending the use of the new method is the fact that it may be applied without the introduction of instruments or chemicals into the inflamed channel.

If the anterior urethra is free from infection a course of not less than six applications of diathermy should be given to the prostate and vesicles. Sometimes seven or eight are required. The treatment should be given twice each week.

In two cases the treatment failed. Gonococci persisted despite repeated treatment. The reasons for the failure were not ascertained. These failures, however, are overshadowed by the conspicuous success obtained in the other cases. They must, nevertheless, be mentioned, and they render it unsafe to make a final and precise statement about the place which diathermo-therapy will ultimately occupy in the treatment of gonococcal prostatitis and vesiculitis.

Infection of the Prostate by other Organisms.—After infection of the prostate and vesicles by the gonococcus there is always a likelihood of secondary infection by other organisms, even after the gonococci have apparently disappeared.

The former may have only a low degree of virulence and produce no effect, other than a slight catarrh of the gland and a persistent gleet. On the other hand, they may be highly virulent and cause symptoms. Organisms of the coliform type may gain entry and cause pain and feeling of malaise and depression. Pyogenic organisms may infect the prostate and produce abscesses.

By reason of the smallness of the number of cases which has been received it is difficult to make any concise statement regarding the value of diathermy in the treatment of such cases. The results, so far, are encouraging. The cases treated by the author had been of very long duration, and other forms of treatment had failed. In two the infecting agents were organisms of the coliform type. The patients sought treatment for their mental depression and incapacity for work which demanded concentration. One had frequent attacks of pain in the perinæum and thighs. Both were medical men and knew the nature of their complaints. Diathermy had the desired effect. Health and mental activity returned and pain disappeared.

Another patient who had acquired gonorrhœa some years before and had apparently been freed from this infection developed abscesses from time to time in the prostate and scrotum. The effects of diathermy were slow but striking. Inflammatory swellings appeared from time to time but did not suppurate. The discharge gradually lessened and finally disappeared, although threads of mucus persisted in the urine. A striking feature of this case was the maintenance of good general health and spirits during and after the diathermy, even when inflammation was still present. The health improved when diathermy was commenced and never retrogressed.

Gonococcal Epididymitis and Orchitis.—Gonococcal infection of the testis and epididymis responds rapidly to diathermy. Pain is quickly abolished, some relief being obtained *during* the first treatment. Tenderness and swelling subside, and after the third treatment and the expiration of ten days there is no pain, no tenderness and no swelling save, in a certain proportion of cases, some thickening of the tail of the epididymis, but without tender-

ness on pressure. Inflammatory thickening of the skin of the scrotum disappears. It is rarely necessary to give a fourth treatment.

These rapid results were obtained in 35 out of a series of 37 cases. The remaining two required more than four applications, but the final results were, in other respects, similar.

It is in the rapid relief of pain that diathermy is so efficient. In most of the cases which have been treated by the author and his co-workers the pain was severe enough to compel the use of sticks or crutches. The facility with which the patients were able to walk at the conclusion of the first treatment was striking.

Diathermy should receive serious trial in cases as soon after the onset of symptoms as possible. By reason of its power in aiding resolution of inflammation the thickening of the globus minor, which so often persists after swelling has disappeared elsewhere, might not occur. Occlusion of the canal would then be prevented. In cases of long duration diathermy is able to abolish the pain, tenderness and swelling, but the thickening of the tail of the epididymis remains and further applications of the treatment do not seem able to cause its disappearance.

After the signs and symptoms of inflammation have disappeared from the scrotum the application of diathermy to the prostate and vesicles should be continued. These parts are included while the contents of the scrotum are being treated, but they require a longer course of diathermy than the testis and epididymis. The scrotal electrode should be replaced by the metal belt and five or six more applications of treatment given to the prostate and vesicles.

The importance of including the primary focus in the treatment of metastatic infection is realised. Some authorities will maintain that infection of the scrotal contents is not metastatic but due to the spread of infection along the vas deferens. It is nevertheless a fact that the results, described above, of the application of diathermy to the scrotum can be obtained by limiting the treatment to the prostate and vesicles and excluding the scrotum. This has actually been demonstrated. It is better, however, in

practice, to include the scrotum during the first three applications, because pain is more quickly relieved if this is done.

When treated by methods other than diathermy a period of three to six weeks elapses before gonococcal epididymitis and orchitis subside. It was in the treatment of cases of the longest duration that diathermy was first tried. By reason of the good results, Dr. Roxburgh, who was at that time assistant M.O. to the V.D. department attached to St. Bartholomew's Hospital, sent further cases directly to the author's department for diathermy without a preliminary trial of other methods. Anterior urethritis, if present, was treated at the V.D. department.

Treatment of Gonococcal Urethritis by Diathermy.

It has already been mentioned that diathermy does not appear able, save in exceptional cases, to terminate gonococcal infection of the anterior urethra with the certainty and rapidity that is the case in endocervicitis and urethritis in women. In most cases of gonococcal infection of the male urethra (except the prostatic portion) diathermy does not appear able to bring the urethritis to an end more quickly than other methods of treatment. Apart from this the treatment of urethritis by diathermy presents two advantages. In the method of application about to be described no instruments or irrigating fluids are introduced. Secondly, the prostate and vesicles are included in the treatment and risk of metastasis or spread of infection is probably prevented.

The following method of application was devised by Dr. C. A. Robinson. The penis is directed downwards between the thighs and pressed against the perinæum. The scrotum intervenes, but if the testes are separated and made to lie on each side of the penis the latter will be separated from the perinæum only by the scrotal skin. A metal electrode, rather smaller in area than that of the dorsum of the penis, is applied to the latter, strips of lint wrung out of strong salt solution separating the metal from the skin.

The body circuit is completed by the prostatic electrode. The current is increased to a strength that produces comfortable warmth without pain. The patient is liable to feel pricking sensations in the regions where the scrotum makes contact with the thighs. They can be prevented by placing thin sheet rubber in between.

The treatment should last for twenty to thirty minutes and be repeated twice weekly.

In the early days of diathermy the treatment of anterior urethritis was attempted by workers on the Continent (Boerner, Santos, Schmidt). A hollow metal tube was passed into the urethra. This constituted the active electrode. The circuit was completed by plate electrodes which were placed on the thighs, perinæum and sacrum. A thermometer was placed in the tube and temperatures of 44° to 45° C. were obtained. Some good results were claimed. It is difficult, by this method, to obtain even heating of the urethra, and burns were sometimes produced. The introduction of tubes into the infected urethra is not without risk.

Section IV

Diseases of Joints, Bones and Fibrous Tissues

In the previous edition of this work it was shown that diathermy had not then procured any striking results in the treatment of chronic arthritis, although it was indicated that the treatment had been effective in three cases of gonococcal arthritis. Considerable progress has, however, been made in recent years. Whereas, in former times, the treatment was applied *to the joints*, it is now localised to the primary focus of infection—whenever such a focus can be found. In cases of gonococcal arthritis diathermy is now applied to the prostate and vesicles in men or to the cervix uteri in women. It has also been found that the cervix is very frequently infected in cases of arthritis (non-gonococcal) in women. The application of diathermy to this part has procured successful results in the great majority of

cases. In cases of osteo-arthritis in men the application of diathermy to the prostate and vesicles has procured good results in a few cases. In these there was no evidence of gonococcal infection. Lastly, the treatment of the pelvic organs in women has secured some good results in cases in which there was no evident disease or infection of the uterus. It has already been suggested that the arthritis in these cases is due to disturbance of the endocrine function of the ovaries. This is merely an hypothesis, but the fact remains that a few cases of arthritis, rheumatoid in type, have been successfully treated by the application of diathermy to the pelvic organs.

What has been stated above is the result of the experience acquired in the author's clinic at St. Bartholomew's Hospital by means of the methods that have been devised there.

Arthritis.

Gonococcal Arthritis.—This variety of arthritis, which was described by the late Sir William Osler as " in many respects the most disastrous, disabling and serious of all the complications of gonorrhœa," responds admirably to diathermy when the treatment is applied to the prostate and vesicles in men, or to the cervix uteri in women. It is essential that the parts named, which are the primary foci from which the infection is disseminated, should receive the treatment. It is not necessary to apply diathermy to the joints also, though sometimes it is advantageous to do so. After the primary foci have been successfully treated the infection of the joints comes to an end.

It has already been pointed out that there is no positive or certain test of freedom of the tissues from infection by the gonococcus. But a lengthy experience in the treatment of gonococcal arthritis has invariably shown that the application of diathermy to the prostate and vesicles, or to the cervix uteri, is always followed by disappearance of pain, diminution of swelling and increase of the range of movement. If the cases are early the joints regain their normal condition. If they are advanced, and permanent structural changes have occurred in the joints, a certain amount of

swelling and limitation of movement remain after the completion of the diathermy. But the joints are then ready for additional treatment by other physical measures, such as massage, movements, galvanic current applications, etc. These will produce further improvement and render the joints useful. This additional treatment will not cause any return of the arthritis because the infection has been abolished. In one of the author's cases there remained a stiff wrist joint. This was forcibly moved under general anæsthesia, but the arthritis did not return.

Diathermy is no less effective in cases in which many joints are involved and the patients compelled to stay in bed. It is successful in young and old patients alike. The youngest patient was a girl of six.

The method of applying diathermy to the prostate and vesicles or to the cervix uteri for the treatment of metastatic infection of the joints and fibrous tissues differs in no way from that which has already been described.

Gonococcal Infection of the Foot.—The treatment is conducted on the same general plan as the joints. The primary foci must be subjected to a course of diathermy. In addition it is advisable to apply diathermy to the feet as well. This should be done after the completion of each application to the primary focus. When the course of treatment of the latter is ended it is necessary, in some cases, to continue the applications to the feet. The latter have to support the weight of the body, and in the efforts of the patients to obtain relief when standing or walking a faulty position of the foot is maintained and further discomfort or pain is developed.

Movements and exercises, as prescribed by the orthopædic specialist, should be practised.

When diathermy is applied to the feet it should be administered *locally*, not to the entire foot. Small padded disc electrodes should be applied to the tender areas on the sides of the tendo Achillis, on the os calcis or wherever they are found.

Non-gonococcal Arthritis in Women.—In cases of arthritis in women there is frequently an unsuspected infection of the cervix. The patient herself may be unaware of any

abnormality in this region. No complaint of discharge is made and there may be no outward or visible evidence of discharge. The patients are usually married women either middle-aged or elderly. Examination, *per vaginam*, through a speculum reveals very frequently an inflamed cervix and the presence of a green or brown discharge at the os externum. In these cases there is no past history of gonorrhœa and no bacteriological evidence of it. Coliform or diphtheroid bacilli or streptococci fæcales or hæmolytici are found.

In these cases the treatment of the cervix by diathermy is followed by the return of the cervix to its normal condition and the appearance of colourless mucus at the os in place of the green or brown discharge. In addition the arthritis is ended in the major proportion of cases. Up to the present time, in the author's experience, the proportion is 70 per cent.

In the successful cases the cervix was doubtless the primary focus of infection. The application of diathermy to this part was followed by a striking improvement of the general health and a disappearance of the pain. Even if the arthritis does not respond to the treatment the patient loses her sallow appearance and "toxic facies."

Arthritis associated with Disturbance of the Ovarian Functions.—The author and Dr. C. A. Robinson have obtained encouraging results in some cases in which there was no evident focus of infection in the uterus or elsewhere. These cases had already received treatment of the teeth or throat when the latter presented abnormality, but the arthritis persisted.

By reason of their apparent relation to the function of menstruation it is suggested that the ovaries were at fault in these cases. Some of the cases occurred in young women when the menstrual function was being established. There was a history of irregular menstruation followed by amenorrhœa and the onset of arthritis. The latter bore a close resemblance to arthritis of the rheumatoid type. Swelling without excessive pain developed around the joints and subluxation was marked in some cases. The application of diathermy was followed by disappearance of pain and swelling, a regaining of full range of movement of the

joints and return of menstruation. One patient, a girl of fifteen, was kept under observation for two years and showed no return of symptoms.

The other cases occurred in elderly women during the period of the climacteric. The menstrual periods came to an end and arthritis developed. The application of diathermy to the interior of the pelvis was followed by disappearance of the symptoms and apparent arrest of the arthritis. In the cases in which the commencement of the climacteric was abnormally early the treatment was followed by temporary reappearance of menstruation. One patient had a menstrual period *after ten years of amenorrhœa*. In another a period occurred after $3\frac{1}{2}$ years. It is suggested that the action of the diathermy was on the ovaries and the restoration of some function dealing with the nutrition of the joints. It is interesting to note that the arthritis was successfully treated in one case in which the uterus and tubes had been removed without the ovaries. In another case in which the ovaries had been removed without the uterus or tubes the arthritis did not respond to treatment by diathermy.

The name " arthritis of the climacteric " may be given to that form of joint disease which occurs during the menopause.

It is too early at present to make any conclusion, but it is possible that diathermy may prove to be an important agent in the treatment of this type of arthritis.

Non-gonococcal Arthritis in Men.—It appears that the prostate may harbour infection (other than gonococcal) which may cause a metastatic arthritis. The gland has been subjected to diathermy in some cases of non-gonococcal arthritis. Successful results have been obtained in a small number, but the frequency of success was far lower than in gonococcal arthritis, being about one in eight.

The local application of diathermy to joints without treatment of the primary focus of infection—when such a focus exists—is usually disappointing. Amelioration of pain is occasionally obtained, but the relief is seldom permanent. Of a series of 45 cases which were treated by applying diathermy only to the joints, 18 received no

benefit; 20 derived temporary relief which lasted for a few hours; in the remaining 7 the relief was of longer duration and the patients felt considerably better at the end of the course. This series of 45 cases received diathermy in the early days when the treatment was applied to the joints only. In the light of present experience there is no doubt that the proportion of successful results would have been much larger, particularly in women, if pelvic organs had been submitted to diathermy.

Osteo-arthritis.—Cases which present the signs characteristic of this type of arthritis are the least unsuccessful in regard to the results following local diathermo-therapy. It is uncertain whether osteo-arthritis is due to metastatic infection. Cases in which there is no evidence of infection, and particularly those which follow trauma, respond fairly well to local diathermy. Pain is relieved in a fair proportion of cases, swelling is reduced and the range of movement increases.

Metatarsalgia (Morton's Disease).

The author has obtained some successful results in the treatment of obstinate metatarsalgia by diathermy. The first two cases described below had resisted other forms of treatment and were sent to the Electrical Department.

Case 1. Male, aged 43. This patient had suffered for eight years from pain in the fore-part of each foot. Surgical operation had been performed on four occasions without lasting benefit. Diathermy was applied twice weekly for a period of three months. Each foot was treated separately for seven minutes at each session. One electrode was placed on the ball of the foot, the other on the calf. As the treatment proceeded the pain lessened and at the end of the course he was able to walk considerable distances without pain. These results lasted for three years. Pain then recommenced. After a second course of diathermy lasting three months the pain was less and felt only after walking.

Case 2.—Male, aged 50. The patient had suffered from acute pain in the fore-part of the right foot and in the left heel. The heads of the metatarsal bones were tender on pressure. Diathermy was applied by way of electrodes placed respectively under the left heel and under the ball of the right foot. The first application procured complete relief for twelve hours. Treatment was continued twice weekly for five weeks. At the end of the course the pain was so slight that the patient was able to resume work.

The third case was one of severe pain in the heads of the metatarsal bones. The metatarso-phalangeal joints presented the radiographic appearance of osteo-arthritis. By reason of the results obtained by diathermy and their permanence it seems unlikely that pain was due to osteo-arthritis.

Case 3. Male, aged 32. The pain developed while travelling in the tropics and was still present when he came to England six months later. There was a history of gonorrhœa. The patient said that he had been cured before the pain in his feet developed. When examined by Mr. Kenneth Walker on his arrival in England there was no evidence of gonococcal infection.

Diathermy was applied to the feet. After sixteen applications the patient was able to take strenuous exercise without pain. Three months later he wrote to say that he was able to walk ten to fifteen miles daily without pain. Some years later his doctor told the author that a permanent cure had apparently been effected.

Coccydynia.

This malady responds favourably to diathermy. All of the author's cases have derived benefit and two seem to have been permanently freed from pain.

Diathermy should be applied by way of two electrodes. One should be introduced into the rectum and the other placed over the coccyx and lower part of the sacrum. The current should be sufficient to produce gentle warmth and be passed for twenty minutes twice or thrice weekly.

Fibrositis.

Cases of pain and tenderness in the regions of origin or insertion of muscles, or in the regions of aponeuroses or fasciæ, respond well to treatment by diathermy. In patients complaining of painful shoulder or hip, or suffering from pain in the lumbar region, etc. an exploratory palpation will often reveal the presence of tender areas in the situations mentioned above.

Diathermy should be applied by way of a well-padded disc electrode, one or two inches in diameter according to the size of the tender area. The electrode should be held by the operator and slowly moved over and around the tender parts, kneading movements being performed for fifteen or twenty minutes. The treatment should be

repeated not less frequently than thrice weekly. It may be given daily with advantage.

At their onset, cases of fibrositis are seldom seen by the practitioner of physiotherapy. At this stage general and local medical treatment should be adopted. At a latter stage, when the patient is able to walk, diathermy should be commenced. A course of treatment lasting from two to four weeks will usually abolish the pain.

If the malady has been of long duration when the patient is first sent for treatment it may be advisable to apply more heroic treatment, such as vibratory massage, or forced movement of the muscles, in addition to diathermy. But the latter should always precede the additional treatment. Whatever the duration of the case, diathermy alone should be applied at the first few visits, and more energetic treatment should be added only if the case makes no further progress.

Section V

Diseases of the Nervous System

It is for the relief of pain due to neuritis that diathermy is mainly used in the treatment of diseases of the nervous system. The treatment is also of value in cases of paralysis, especially when groups of muscles are affected and local hypothermia, congestion, cyanosis, etc. are present. When the lesion responsible for the pain or paralysis is inflammatory it is possible that diathermy may play some part other than the treatment of symptoms. It may aid the resolution of the inflammation and thereby treat the more immediate effects of the agent responsible for the disease.

Peripheral Neuritis.

The value of heat in procuring relief of pain is well known. Many cases of painful neuritis can be relieved by applying the simpler methods of thermo-therapy which heat the superficial regions only. Many will resist this treatment and fail to respond also to anodynes and counter-irritation. Diathermy has repeatedly proved its value in cases which

have resisted simpler methods of treatment. The opportunity of treating virgin cases has very rarely occurred to the author, though the few that were treated by diathermy were quickly and permanently freed from pain; but it is in the treatment of cases that have resisted simpler methods that the value of diathermy has been established.

Some experiments were conducted by the author in order to ascertain the relative value of diathermy and "epithermy" in the treatment of painful neuritis. A number of patients were given courses of treatment by radiant heat. Some obtained permanent relief. Others derived benefit of short duration, the pain returning soon after the conclusion of each application. These were then subjected to diathermy. All of them derived relief for longer duration and most were freed from pain at the end of the course.

Relying on the experience of many years, the author prefers to use diathermy for the treatment of painful neuritis and has obtained a larger proportion of successful results by its means than by other forms of physiotherapy.

Methods of Application.—When definite tender areas can be discovered in the region where pain is felt, the most effective method of applying the diathermy is the following.

The active electrode, a metal disc, one inch or one and a half inches in diameter, slightly convex on the surface, padded with lint and covered with chamois leather, is placed in contact with the skin. The padding is moistened with strong saline. It is pressed against the tender area. An indifferent electrode of larger area is placed on the opposite side of the limb or trunk.

In place of the indifferent electrode another may be applied to the vertebral column so as to lie over the roots of origin of the nerves along which the pain is referred.[1]

The current is now started and slowly increased until the skin under the disc electrode becomes as hot as can be borne without pain. It is safest for the patient if the

[1] *Three* active electrodes may be applied and three tender regions treated simultaneously if the diathermy machine is fitted with three terminals for conveying current to the patient. In cases of sciatica the electrodes may be applied to the back of the hip, to the front of the knee and to the ankle. A current distributor (p. 79) is necessary in order to prevent uneven heating of the three regions. The writer first saw this method used by Dr. Kowarschik at the Kaiser-jubiläumsspital, Vienna.

operator holds the disc electrode in position. He can then feel the skin from time to time (after stopping the current) and note whether it is getting unduly hot. The patient can usually tell when the temperature is becoming too high, but occasionally this is not the case, and if the precaution mentioned is not taken, burns may occur.

It is advisable slightly to shift the position of the disc electrode from time to time. Since the maximum heat is produced in the tissues under the periphery of the electrode, slight occasional movement of the latter will secure more even heating.

Each tender region should be treated from five to ten minutes.

An alternative procedure is to place the patient on a condenser couch and treat the painful areas in the manner described. The roots of origin of the nerves may then be subjected to diathermy in the same way.

When no tender area is present the region to which the pain is referred should be treated in the way described. Disc electrodes of larger diameter may be employed if the pain is referred to an extensive area.

This treatment should be given as frequently as possible, even twice daily if this can be done. When only one application can be made daily it should be given as late in the day as convenient, in order that the relief may be continued as far through the night as possible. If the periods of relief are short, or do not lengthen, the electrodes should be held in position for longer periods.

Results.—It is not uncommon for the patient to feel some aggravation of the pain *during* the application of diathermy. As soon as the part under the active electrode begins to get warm he will sometimes say that the heat has "brought the pain out." This is not an unfavourable sign. It soon subsides when the application is over, and considerable relief follows.

The patient seems to have no difficulty in distinguishing this temporary increase of pain from that which would be caused by undue heating of the skin. The former is often felt, in addition, in parts other than that under the disc electrode.

After the first application relief is felt from two to ten

hours. Cases that are going to respond favourably and derive considerable or complete relief from a course of diathermy are comfortable for progressively longer periods as the course proceeds, and although the pain tends to return in the intervals between successive applications it does not attain its original severity. If the pain persistently returns with undiminished severity between each application the case is unlikely to derive much benefit.

It has already been stated that the increase of pain which is occasionally felt *during* diathermy quickly subsides after the application is over. Increase of pain which persists after the diathermy is, in the author's experience, extremely uncommon. In other words, diathermy very rarely makes the patient worse. In one case of brachial neuritis, in a woman of fifty, the patient said that the pain gradually increased after the first application of diathermy and was so severe at midnight that her doctor had to give her "an injection." This case was in a hospital patient. No other case of a similar kind has occurred in the author's experience.

Cases of neuritis in the upper extremity respond, on the whole, more favourably than those in which the neuritis is present in the lower limb. The probable reason for this is the inability of the patient to keep the lower limb at rest when he is coming for treatment. The upper extremity, on the other hand, can be kept at rest in a sling.

Cases of long duration, *i.e.* a year or more, are difficult to relieve, at any rate permanently, by diathermy alone. This is especially the case with neuritis of the sciatic nerve. Adhesions may have developed—in these cases—between the nerve and the hamstring muscles. Treatment more heroic than diathermy should then be applied, such as strong vibratory massage or the production of powerful rhythmic twitches of the hamstring muscles, either by the static wave current or the slowly interrupted faradic current. Such treatment, however, is considerably more effective if each application is preceded by diathermy.

At the onset of sciatica, or of neuritis elsewhere in the lower extremity, especially if the pain is severe, it is questionable whether it would be wise for the patient to receive diathermy if a journey were rendered necessary. The benefit that would be derived from the treatment might

easily be nullified even by a short walk. The author treated a case of sciatica soon after its onset, and although each application caused great relief no permanent progress was made. Eventually the case became worse and the patient was compelled to stay in bed.

Untoward results of this kind, however, do not always occur. At the request of his doctor the author treated a case of sciatica, in a gentleman, aged 55, accompanied by severe pain. The treatment was commenced on the sixth day. The patient walked with the help of a stick, with his knee slightly flexed and his heel off the ground. After receiving the first application the pain was so much relieved that he was able to walk naturally, and without pain, from the room, down a long passage and enter his car. This treatment was given at 5.30 p.m. The pain returned about midnight and became severe during the small hours of the morning. Diathermy was repeated daily for five days. Each application was followed by great relief, but with subsequent recurrence in the early hours of the morning, though with less severity. On the fifteenth day the pain was slight. The patient made a complete recovery. The pain had not returned after ten years.

The opportunity of treating a case at its actual onset is rarely obtained, but it occurred in the following case. The porter in attendance at the author's clinic was noticed to develop a limp one afternoon while at work. He complained of pain in the back of his hip and knee. A diagnosis of sciatica was made. Diathermy was administered each morning and afternoon. The patient derived considerable relief and was able to perform his duties each day. Although the pain returned each night its severity gradually lessened. After eleven days it disappeared entirely. There has been no return during the subsequent three years.

The major number of the cases which have been received, however, were those that had already received fruitless treatment by drugs and external applications of anodynes or counter-irritants. Recent and severe cases should be advised to rest in bed until the acute stage has passed.

In the following table are given the particulars of ten consecutive cases of brachial neuritis which were treated by the method described above. They give an idea of the

results that may be obtained in the routine treatment of this malady by diathermy.

	Duration of Complaint.	No. of treatments.	Result.
Case 1. Female, 37	3 months	12	Severity of pain reduced by diathermy after ionisation had failed. Pain was not entirely abolished, and slowly returned after patient discontinued treatment.
Case 2. Female, 25	2 weeks	16	Relief of pain commenced at once and lasted for increasingly long periods after each treatment. Recurrence of slight pain after work was resumed, but at end of course it disappeared.
Case 3. Male, 42	4 months	16	Relief commenced at once. At end of course pain had entirely disappeared.
Case 4. Male, 33	2 years (intermittent)	12	Gradual reduction in severity of pain. At end of course was felt only slightly on violent movement of arm.
Case 5. Female, 50	7 months	5	Diathermy produced relief for one hour only after each treatment.
Case 6. Male, 51	10 weeks	10	Diathermy produced temporary relief and the pain was lessened, though not completely abolished, at end of course. Ionisation had been tried for four weeks without avail before the diathermy.
Case 7. Female, 34	8 weeks	16	Improvement commenced at once, and pain was soon reduced to a slight degree, but could not be entirely removed.
Case 8. Female, 65	6 months	8	Relief slight and short after each treatment; no permanent reduction in severity of pain.
Case 9. Female, 20	1 week	15	Complete relief at end of course.
Case 10. Female, 38	6 months	10	Complete relief at end of course. Pain returned six months later. A second course of diathermy abolished the pain for twelve months. Patient is now under treatment for the third attack.

Below are given particulars of fourteen cases of sciatica which were treated by diathermy.

	Duration of Complaint.	No. of treatments.	Result.
Case 1. Male, 38	7½ years (intermittently)	4	Relief for about twelve hours, when pain returned with undiminished severity.
Case 2. Female, 48	4 weeks	3	Relief for some hours, pain returning with much less severity.
Case 3. Male, 55	3 weeks	8	Relief for gradually lengthening periods. Pain was not entirely abolished. Ionisation eventually completed cure.
Case 4. Male, 33	5 months	4	Pain reduced to slight degree.
Case 5. Female, 28	6 months	7	Complete freedom from pain for twelve hours or longer. Pain could not be entirely abolished by diathermy.
Case 6. Female, 63	5 years (intermittently)	7	Slight and temporary relief.
Case 7. Male, 48	3 months	12	Relief of pain for a few hours. Pain was only slight at end of course.
Case 8. Female, 19	3 months	12	Gradually increasing relief for lengthening periods. Slight "stiffness" in leg at end of treatment.
Case 9. Male, 58	5 weeks	5	Slight relief of pain at end of course. Further relief after ionisation.
Case 10. Male, 53	10 months	7	Slight relief from diathermy. Previous applications of ionisation and sinusoidal current were ineffective.
Case 11. Male, 45	2 weeks	4	Considerable relief of pain. Further improvement by ionisation.
Case 12. Male, 19	3 weeks	5	Slight relief. Further improvement by ionisation.
Case 13. Male, 56	3 months	11	Great relief from diathermy. Pain only slight at end of course. Ionisation with quinine and salicylic ions had been previously tried and found ineffective.
Case 14. Female, 54	2 years	12	Diathermy produced relief after sinusoidal current failed. Duration of relief increased till pain became slight. Six weeks after treatment ceased the pain returned and was somewhat severe.

Paralysis Agitans.

The severest test for a new method of treatment is applied when the treatment is tried for diseases for which no known methods are successful. The disease in which, in the writer's experience, the test has shown the nearest approach to success is paralysis agitans. Cure or *permanent* relief has not been obtained, but in some cases a considerable degree of relief has been obtained, and the improvement has been maintained for some months.

Case 1.—Female, aged 55. This patient had suffered for two years from progressive weakness of the right hand and arm and tremors. Walking had induced early fatigue. Various forms of electrical treatment had been tried, including cerebral galvanism, which had been applied by the late Dr. Lewis Jones. On February 10th, 1914, treatment by diathermy was commenced. The current was directed along the upper limbs, and its strength was sufficient to cause a rise of temperature of the whole body. The patient sweated freely during the application of the current. Treatment was given twice weekly.

On February 13th she felt better in general health. On March 3rd she was able to resume knitting and needlework, and she could write more steadily and with less fatigue.

On April 17th the treatment was discontinued. The improvement in general health was maintained during the course of treatment, and headache, which had been constant before, was abolished. The tremors did not cease, but manual work could be undertaken with less fatigue and skilled movements could be performed without much difficulty.

The benefit resulting from the diathermy was maintained for six months. A second course of treatment was commenced, but could not be completed as the patient left London. No communication from her was afterwards received.

Case 2.—Female, aged 56. She was an in-patient at St. Bartholomew's Hospital, under care of Dr. (now Sir Wilmot) Herringham. Her chief complaints were the weakness of her arms and legs and inability to do fine work with her hands. General diathermy was commenced on July 3rd, 1914. Eight applications were made. On July 20th the patient went away for a holiday, and treatment was suspended. The improvement during the treatment was great, and was especially noticeable in the gait, and the patient said she could walk without "scuffling." On September 17th she returned and reported that she had maintained her improvement.

In May, 1915, treatment was resumed on account of recurrence of symptoms. The subsequent history was not obtained.

Case 3.—The patient was a doctor, aged 66, who had retired from practice some years before the onset of the disease. He complained of a general weakness and difficulty in walking.

A long course of treatment could not be given on account of the length of the journey which he had to undertake. He said that he felt much better after the diathermy. The briskness of his movements was evident after each application, and he was able to walk

at an increased pace. The improvement was maintained for a few months, but eventually the patient was confined to his room owing to increasing weakness, and he died at the age of 70.

Case 4.—Male, aged 65. He had noticed tremors of his hands for many years, but of late they had been more evident. He had felt some difficulty in walking during the past few weeks and a tendency to fall forwards.

General diathermy was commenced on December 13th, 1918. Twelve applications were made in thirty-four days. At the end of this time there was no evident alteration of the gait or lessening of the tremors. The patient said that he felt much better in general health. Six months later he desired a repetition of the treatment. Before he was able to make plans mental symptoms ensued, and the patient became violent at times, so that detention under observation was necessary.

The cases above described comprised the first three successes obtained by the author in the treatment of paralysis agitans by diathermy. All the cases were in patients older than 54. Other patients were treated; two were men of 39 and 49 respectively, and one was in a woman of 31. These derived no benefit. It seems, then, that diathermy was successful only in elderly patients. This opinion has been confirmed by further experience. Patients under 50 derive no apparent benefit.

Patients suffering from encephalitis lethargica and presenting the Parkinsonian syndrome do not seem to respond to diathermy.

A patient suffering from paralysis agitans has been under treatment by the author at intervals for the past three years. The symptom for which he sought treatment was vocal huskiness and difficulty in commencing articulation. Involuntary tremors of the hands and fingers were persistent. During the past six months these tremors have been decidedly less and often absent. The disease appears to have made no progress. The vocal symptoms have not yielded to general diathermy. Laryngeal diathermy is now being tried for them. At the time of writing they appear to be somewhat less evident.

Anterior Poliomyelitis (Infantile Paralysis).

Prof. Bordier, of Lyon, has called attention to the therapeutic powers of diathermy in infantile paralysis. The object of the treatment is to raise the temperature of the

cold paralysed extremities. Progress in paralysis is greatly retarded by cold. By reason of its ability to heat the deep as well as the superficial structures of the limbs, diathermy is an ideal method of raising the temperature of the paralysed extremities. The latter retain some of the warmth imparted to them by the current even as late as twenty-four hours after the treatment.

To apply diathermy a large plate electrode should be applied to the patient's back and connected to one of the terminals of the machine. The other electrode should be applied to the sole or palm according to the extremity affected. If necessary an electrode should be placed on each sole or palm and both electrodes connected to the other terminal of the machine. A watch should be kept on the patient and the current maintained at a strength that keeps the legs or arms comfortably warm. An alternative method is to replace the palm or sole electrode by a padded disc and stroke the latter slowly and rhythmically along the extremity over the various muscles.

The author does not think diathermy can replace treatment by the rhythmically varied sinusoidal current in full-length baths. It is, however, a valuable additional treatment, particularly when the paralysed limbs are very cold and cyanosed, especially in the cold months. It is possible, also, that the slight elevation of temperature of the trunk may relieve congestion and improve the circulation of the spinal cord.

Neuralgia associated with Herpes Zoster.

Diathermy is sometimes successful in abolishing the pain which often persists after herpes zoster.

A patient of 65, a carman, felt pain in his shoulder and arm. A few days later a rash appeared in the same region, and pain became very severe. Erythema was visible in the area where pain was referred and some minute red spots were seen. Diathermy was applied by way of electrodes placed on the forearm and on the spine in the region of the cervical enlargement of the cord. Treatment was given twice weekly. Relief was felt after the first application. After a month the pain was completely abolished.

Other cases also have derived considerable relief. In one case in an old man of 80 the treatment was unsuccessful.

Trigeminal Neuralgia.

The author has treated four cases of this disease by diathermy, but the results were disappointing. By reason of the success that may be obtained by means of the galvanic current of high intensity he has abandoned further trial of diathermy for trigeminal neuralgia.

Of other pain-producing diseases of the nervous system the author has had a small but successful experience of *tabes dorsalis* and *intercostal neuralgia*. The lightning pains which may occur in the first mentioned were relieved by diathermy. One electrode was placed on the vertebral column over the site of the lesion in the posterior roots of the spinal cord; the other was applied to the periphery where the pain was most acute. Great care should be exercised in the treatment, because the patient may be unable to perceive the sensation of heat. The current should be increased slowly and the skin should be heated a slight degree only.

Section VI

DISEASES OF THE CARDIO-VASCULAR SYSTEM

The power of diathermy to raise the temperature of the blood and cardio-vascular system is the most evident reason why this form of treatment is of value in certain diseases of the heart and blood vessels. It has already been shown that the blood is heated when regions of the body, especially the limbs, are subjected to diathermy. The passage of the heated blood along the smallest vessels and through the *vasa vasorum* of the larger arteries and through the coronary vessels must raise the temperature of the entire cardio-vascular system. Heat diminishes the frictional resistance encountered by the blood in the arterioles and capillaries, lowering the viscosity of the circulating fluid. The blood, therefore, can circulate with greater ease and the work of the heart is diminished.

Heat also tends to lessen vaso-constriction, and if this is brought about the circulation is further aided.

Lastly, it is not unreasonable to suppose that the heating of the blood aids the circulation through the coronary vessels and thereby improves the nutrition of the heart.

When describing the effects of diathermy on the circulatory system in health it was mentioned that hyperæmia was produced in the region traversed by the current and that the blood pressure fell and the pulse rate increased. These effects can be readily attributed to the action of heat. In disease a reduction of the high blood pressure which frequently follows general diathermy can likewise be attributed to the heat produced by the current. It is unnecessary to assume that the current has some other mode of action on the cardio-vascular system. No other mode of action has been demonstrated. On the other hand, the effects of heat are far-reaching. To attribute them to some other unknown action is to envelop the subject in obscurity and offer no aid to rational therapy.

Of the diseases of the cardio-vascular system that can be ameliorated by diathermy, first mention must be made of arteriosclerosis with high blood-pressure—the " hyperpiesia " of Sir T. Clifford Allbutt. Diathermy is also of value in some cases of intermittent claudication. Good results have also been obtained in angina pectoris. When high blood-pressure and arteriosclerosis are associated with chronic interstitial nephritis little benefit is obtained from diathermy.

Arteriosclerosis with high Blood Pressure.

(Hyperpietic arteriosclerosis; hyperpiesia.)

There is no doubt that high-frequency currents, capable of producing diathermy, can play a valuable part in the treatment of the above-mentioned disease. Symptoms can be relieved and the blood-pressure may be lowered. Diathermy can procure these results in cases which have failed to respond to medical and dietetic treatment.

The late Sir T. Clifford Allbutt wrote: [1] " Of the effects of the high-frequency current in reducing excessive arterial pressure I have now considerable, if second-hand, experience.

[1] *Index of Treatment.* By Robert Hutchinson and James Sherren. 8th edition, p. 86.

In many cases in which it has been tried for me, I have been led to believe that it had a good and abiding effect in this direction. Until diastolic blood-pressures are more systematically measured by therapeutists their reports will be incomplete; but in some of my cases these methods have been carefully observed. Dr. Lewis Jones, who has also procured relief in high-pressure cases from high-frequency currents, attributes the relief to 'diathermy.' The 'dosage' of the current is of great importance; probably the doses in general use are too weak."

High-frequency currents were widely used for reducing abnormally high blood-pressure before the importance of the heat which these currents could generate was realised. Good results were reported, especially by workers in France. Some workers obtained a reduction of the pressure. Others, however, were unsuccessful, save in a small minority of cases. Occasionally a *rise* was obtained. The currents generated by the original clinical type of apparatus produced little heat. As time progressed the apparatus was modified or redesigned. The amperemeters indicated stronger currents and more heat was produced within the body. In the early days of high-frequency therapy the results were not attributed to the production of heat. Even at the present day a few workers maintain that the currents produce their effects in some other way or in some additional way. Reliance is still laid on the amperemeter for the measurement of the "dose," although the readings of this instrument are fallacious for the purpose. Until there is less divergence of opinion, less inaccuracy in dosage, and more standardisation of methods and apparatus the progress of electrotherapy in the treatment of the disease under consideration will be delayed.

In the following account the author writes from his own experience obtained by the use of currents that produced general diathermy and a rise of the body temperature, believing that the effects of the treatment are due to the heat produced in the tissues. Methods of applying the treatment are first described. The results, including the effects on the blood pressure, are illustrated by reports of cases.

Methods of Application.—These are the methods of procuring general diathermy. They are described on p. 130. The current may be directed along the extremities from hand to hand and from sole to sole. Or the condenser couch may be used, provided that the diathermy machine is suitable for working in connection with it. There is no essential difference in the results obtained by the direct method of application and the condenser couch method. These methods secure a general heating of the body and the cardio-vascular system as a whole, the parts lying on the path of the current being heated *directly* by the current, the others *indirectly* by convection.

When cardiac pain is present it is advantageous to apply diathermy *directly* to the heart as well. In general applications this organ is heated by convection, but it is probable that the anterior wall, at any rate, is heated more uniformly when the current is applied by way of electrodes placed in such a situation that the organ is included between them. Plate electrodes should be used. One should be placed on the front of the chest and cover the præcordium. The other should be a little larger in area and placed on the back.

The general body temperature cannot be raised more than a trifling amount when diathermy is applied to the heart. The blood does not remain long enough in the heart to be appreciably heated during its stay in this organ. Its resistance, too, is low and less of the current energy is transformed into heat.

When a particular region is believed to be the field of arteriosclerosis, or is the site of pain, it should be included on the path of the current, either when general diathermy is administered or directly afterwards. Thus if the legs are cold or liable to cramp the current should be directed along them when general diathermy is given. If there is pain in the head the current may be applied to the latter after general diathermy has been administered. If the circulation in the hands or feet is deficient they should also be submitted to diathermy by the methods described on p. 125.

Dosage.—When general diathermy is administered the treatment should procure general increase of the warmth of the body. The strength and duration of the current

should be sufficient to procure a rise of 0·4° F. at the first treatment. At the second a rise of 0·6° may be obtained. At subsequent visits the temperature should be raised slightly higher, say by 0·8° or 1°. Patients who have a subnormal temperature can be heated through a wider range than those whose temperature is 98·4°. The elevation of the oral temperature to 99° is usually sufficient and is the measure of an adequate dose. On occasions a trial must be made of a larger dose if the symptoms are not relieved. About twenty minutes should be occupied in administering the first treatment. When the dosage is increased it is better to lengthen the duration of the séance than increase the current.

As soon as the patient begins to feel relief the temperature need be raised no higher.

The blood-pressure, systolic and diastolic, should be measured at the beginning and end of each visit. Treatment should be continued for a time after relief is obtained. About a dozen applications constitute a course of treatment. Some cases require more. It is advisable to repeat the course once or twice a year.

On occasions it will be found that although relief of symptoms occurs the blood-pressure shows no permanent fall. When this is the case the dosage should be cautiously increased in the endeavour to reduce the pressure if it is thought that the latter is still too high. It should not be reduced below the value necessary to secure a sufficient blood supply to the tissues. After symptoms have disappeared without material reduction of blood-pressure a considerable increase of the dose is necessary to procure reduction, and if the latter is obtained the patient may feel less well and complain of dizziness and weakness.

When diathermy is applied directly to the heart the applications should at first be short, say, five minutes, and the current strength sufficient to produce a distinctly palpable increase of warmth of the skin under the active electrode. A thermometer may be placed in the pad under the metal with its bulb near the edge and a rise of five degrees obtained at the first visit. At subsequent visits the length of application and strength may be slightly and

progressively increased until relief is obtained. There is a possible risk of syncope if the dosage is excessive at the first visit, both when general and cardiac diathermy are given.

Results of Treatment.—(1) *Symptoms.* It is a common occurrence for patients to obtain relief from cardiac pain, headache, dyspnœa and general weakness after a course of diathermy. Buzzing noises "in the ears" are less easy to remove, but some relief is usually obtained. Relief of symptoms is maintained for three to six months or longer. A repetition of the treatment will then again procure relief. It is unusual for diathermy to fail in procuring, at any rate, some relief, but a small number of cases of long duration have been encountered in which diathermy failed altogether when given in moderate doses (without material lowering of the blood-pressure), and made the patient worse when the dosage was excessive and the pressure considerably reduced. A case of this kind is described (No. 3, see below).

(2) *Blood-pressure.*—The following account of the influence of a course of diathermy on the blood-pressure and its relation to the symptoms of the patient is based on the author's experience. It is difficult to make any precise conclusion at present, nor has the gain of experience made the task easier. Generally, it has been found that patients whose systolic pressure is under 200 mm., say 170, 180 or 190 mm., derive benefit and lose their symptoms without material reduction of the pressure below its original value at the end of a course of diathermy. At the conclusion of each application the systolic pressure falls a few millimetres, but it regains its original value before the next treatment. Occasionally a fall is not obtained. When no benefit is derived and the doses are increased until a lasting fall of pressure occurs the patient feels no better and may feel worse.

On the other hand, when the pressure is well above 200 mm. at the commencement of treatment, say 230, 240 mm. or higher, the effect of a course of diathermy is a reduction of the pressure to the vicinity of 200 mm., and usually relief of symptoms. In these cases the fall of pressure noted after the earlier applications does not return to its original value.

In the author's experience the symptoms and their relief by diathermy do not bear a close relationship to the effects of the treatment on the blood-pressure. As stated above, some cases derive relief without permanent lowering of the pressure, while others, equally benefited, show a reduction which is maintained after the treatment is completed. Others show a reduction without deriving benefit. It is suggested that the value of diathermy lies in its power to aid the circulation in the periphery and maintain an adequate blood supply to the regions where the vessels have a diminished calibre. The same pressure may be needed to ensure the supply in spite of the lowered peripheral resistance; on the other hand, the reduction of the peripheral resistance may be sufficient to enable a lower arterial pressure to provide the needed supply of blood; when this is the case the systolic blood-pressure will maintain a lower value.

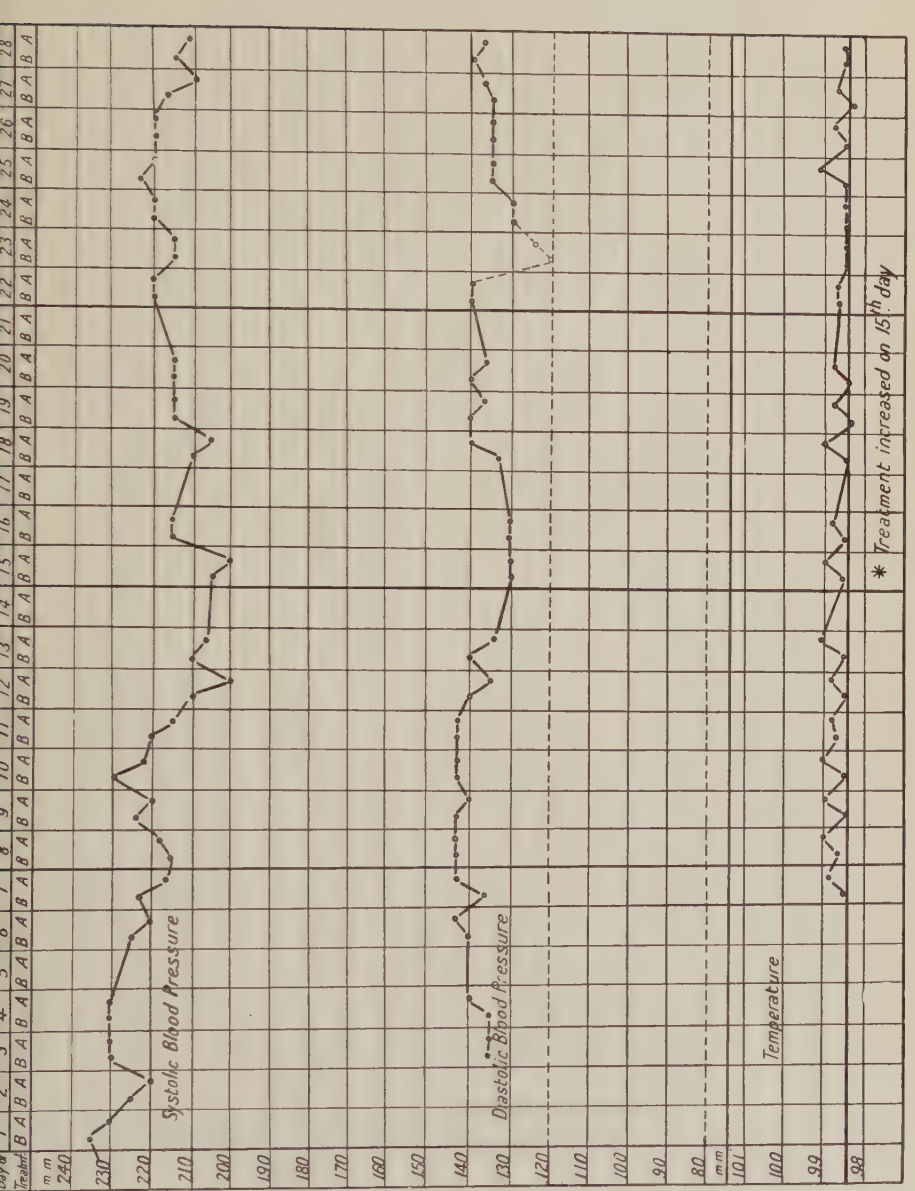
Below are given the details of some cases. No. 1 shows that considerable benefit was derived without permanent reduction of the blood-pressure. No. 2 is a case of hyperpiesia which was treated by diathermy in its early stage and kept under observation for a number of years. Great relief was obtained by the treatment, but without permanently lowering the blood-pressure. In No. 3 no benefit was derived even after a fairly considerable lowering of the pressure.

Case 1.—T. J. H., bricklayer, aged 63. For twelve months he had complained of pains in both arms, especially the left; inability to sleep at night on account of "loud throbbing in the head" as soon as he laid his head on the pillow; headache, severe in the morning, but getting better during the day. He had occasional attacks of faintness, and on the least excitement he "shook all over."

On examination it was found that his arteries were much thickened and tortuous. His systolic blood-pressure was 235 mm. The apex beat was in the fifth space, $\frac{1}{2}$ in. external to the mid-clavicular line. Its impulse was heaving and just visible. The first sound was accentuated in the mitral area. There were no added sounds. Urine: S.G. 1020; albumen present, but less than 0·01 per cent. Calcium oxalate crystals formed the bulk of the deposit; a few colourless corpuscles were seen and one hyaline cast was found.

Treatment by diathermy was commenced on August 28th, 1919. The current was passed for ten minutes daily from hand to hand. After a fortnight it was passed, in addition, for ten minutes from foot to foot.

Improvement commenced at once. The following notes were taken of his condition during the treatment:—


Days
Treatment
mm
Systolic Blood Pressure
Diastolic Blood Pressure
Temperature
* Treatment increased on 15th day

Sept. 4.—Much improved. Sleeps better; less pain. B.P. 218 (systolic), 145 (diastolic).

Sept. 10.—Improvement continues. Says he has not felt so well for months. Can use his left arm fairly well. B.P. 208 (systolic), 135 (diastolic).

Sept. 12.—Treatment increased. Diathermy from hand to hand ten minutes, foot to foot ten minutes.

Sept. 17.—General condition continues to improve. He is much brighter, and his generalised aches and pains are troubling him less. Says he sleeps much better, but still gets throbbing in his head when he lies down at night. In spite of the increase in the duration of the diathermy treatment, the B.P. has risen again, and is now fairly steady at about 220 (systolic), 140 (diastolic).

Sept. 25.—There has been a slight fall in B.P. again during the last three days, 215 (systolic), 137 (diastolic). He is quite certain himself that he is much better. Treatment to be discontinued for a month.

Nov. 6.—Continues better but still has headache. Blood-pressure has risen again to 240 (systolic), 135 (diastolic). Arm is no worse now than when he left off treatment, and is much better than when he commenced.

Diathermy was given six days for fifteen minutes from hand to hand. The systolic pressure before treatment was 240 mm. After treatment it was 220 mm. The diastolic pressure remained the same (135 mm.).

The figures representing the systolic and diastolic pressures are shown in the chart (p. 197). This chart and the measurements of the pressure were made in the author's clinic by Dr. C. G. Teall.

The pressure was measured each day before diathermy and fifteen minutes after. It will be noted that the diathermy usually produced a slight fall of pressure after each application, but the tendency was for the pressure to rise again before the next application. The improvement in the patient's condition bore no evident relation to the blood-pressure.

The temperature before and after each application is recorded on the chart. This gives an approximate measure of the dosage.

Case 2.—Lady, aged 50. This patient had suffered, since 1912, from attacks of pain in the heart and left arm, shortness of breath, and severe headache. Three of the attacks of pain had been very severe. On examination, in July, 1915, the systolic pressure was found to be 170 mm. The pulse was arrhythmic, and there were many premature beats. Occasionally the pressure reached 190 mm. The arteries were slightly thickened. The apex beat was felt in the 5th space, 4 inches from the middle line. There were no added sounds. There was no albuminuria.

Diathermy was commenced on July 14th, 1915. It was applied to the heart because cardiac pain was the most prominent symptom. Thirteen applications were made in twenty-one days. The length of each application was gradually increased from five minutes to fifteen minutes. At the end of this course of treatment all the symptoms had disappeared and the patient felt very well. Each application slightly lowered the systolic pressure, but the latter usually regained its original value before the next application.

A second course of treatment was given in December, 1915, as the symptoms had returned. The pressure was 185 mm. Fourteen applications were made, in the same way, during thirty-one days. The pressure was at no time lower than 170 mm., and usually it was 180 mm.

A third course was commenced in June, 1916. The patient complained of noises in her head, headache and palpitation. Thirteen applications of cardiac diathermy were given in thirty-one days. The symptoms were completely relieved.

A fourth course was given in September, 1916, as the patient complained of headache and noises in her head. Three applications of diathermy were given in three days. The headache was relieved and the pressure was reduced from 195 mm. to 180 mm.

A fifth course was given at the end of the year (1916). The symptoms (headache, momentary attacks of vertigo, pricking sensations in the chest) were relieved. General diathermy was given (five applications).

The sixth, seventh, and eighth courses were given in 1917 and 1918. Each was followed by considerable relief, the patient feeling much better. The mental depression felt before the courses of treatment disappeared entirely. The noises in the head could not be abolished completely.

The ninth course was commenced in January, 1919. The pressure was 210 mm. The patient complained of the customary symptoms and, in addition, to momentary attacks of blurring of vision. This course could not be completed as the patient left London to reside in the country. The pressure was reduced from 210 mm. to 188 mm. during the course, but it rose to 200 mm. when she left. The symptoms were partly relieved.

The patient came again for treatment in November, 1922, saying that she had suffered during the past few weeks from pain in her chest and left arm, but not from headache. Her pressure was 195 mm. She stayed for a course of three applications only, but derived relief. At the end of the third, the pressure was 170 mm.

In December, 1926, she came for a single visit. She stated that she had felt fairly well during the past four years and had had no pain in her heart, and rarely headache. Her chief trouble was shortness of memory. On examination it was found that the heart was enlarged to the left, the apex beat being in the 5th space and 4½ inches from the middle line. There were no added sounds. The systolic pressure was 182 mm. and the diastolic 120 mm.

In March, 1927, she came for an eleventh course of treatment. Her symptoms were no more than those described on the last visit. Her pressure was 200 mm. (systolic) and 120 mm. (diastolic). At the time of writing she is under treatment. She stated that she had never had a return of the severe heart pain or prolonged headache since she had commenced her first course of diathermy in July, 1915.

Case 3.—Male, aged 65. Complained of shortness of breath and "great weakness." The dimensions of the heart could not be ascertained on account of advanced emphysema of the lungs. The pulse was infrequent (60 per minute) with many premature beats. The arteries were markedly sclerosed. The systolic pressure was 240 mm.

General diathermy was applied. After the first treatment it was lowered to 230 mm. Three days later it was found to be 240 mm. It was reduced by diathermy to 225 mm. The patient felt no better before or after treatment. Four days later he said that he felt "much weaker." The pressure was measured and found to be 195 mm. No further diathermy was given.

Angina Pectoris.

Diathermy has been warmly lauded by Dr. Franz Nagelschmidt as a method of treating angina pectoris. In his *Lehrbuch der Diathermie* he has described cases in which attacks of angina had occurred before the treatment, but had remained free from further attacks after diathermy. In two of the cases no return of pain had occurred during the two years while they were kept under observation.

The author has found cardiac diathermy very effective in procuring relief of pain in the region of the heart in cases of arteriosclerosis. A diagnosis of true angina could not be made, however, except perhaps in the case described below.

Male, aged 61. This patient complained of dizziness and of attacks of severe pain in chest and left arm. These symptoms had lasted for three months. He had been under medical treatment, as an out-patient at a heart hospital, without deriving much relief.

On examination, his arteries were found to be hard, though not markedly so. His systolic pressure was 148 mm. Owing to emphysema his apex was impalpable, and the area of cardiac dullness was obliterated. The aortic second sound was accentuated.

One electrode was placed on the præcordium, the other on the back. After five minutes the pressure fell to 138 mm. After ten minutes the patient showed agitation and trembled. The pressure was found to be 160 mm. After fifteen minutes it was 150 mm. The treatment was stopped. The patient said that he felt much better and "lighter in the head." Four days later he returned for a second treatment. He said that he had felt very much better and that the pain had disappeared. The same treatment was given. The pressure before the treatment was 140 mm. After five minutes and again after ten minutes it was found to be a little higher. After fifteen minutes it had regained its original value. The patient remained quite free from symptoms. A third treatment was given three days later; the pressure then was 140 mm., and after fifteen minutes it had fallen to 135 mm. without any preliminary rise.

This patient was able to resume work after the treatment.

In a letter to the *British Medical Journal* (July 10th, 1926) Dr. J. N. Dyson mentioned the good results he had obtained by means of diathermy in angina pectoris. Six cases were treated. One was in a man of 64 who had suffered severe attacks of pain each day. Eighteen applications of cardiac diathermy were given during six weeks. The patient remained free from further attacks during the following two years. At the expiration of this period he disappeared from observation. Diathermy had been recommended for this patient by Dr. John Hay, of Liverpool.

Dr. Dyson stated that he had obtained equally good results in three other severe cases and two which were milder. The one failure was in a patient of 74 who improved so much after two weeks' treatment that he refused to attend regularly. Later on he had a recurrence and died.

Intermittent Claudication.

When this symptom is present in cases of arteriosclerosis it can be relieved to some extent by diathermy. The current should be directed along the lower extremities by way of electrodes applied to the soles of the feet. The author has, however, obtained better results by means of the constant (galvanic) current, the legs being immersed in hot water in a Schnee bath. This treatment appears to relieve the symptom for a longer period. General diathermy should, however, be given in addition if arteriosclerosis is evident in other parts of the body.

Raynaud's Disease.

Neither by local nor by general diathermy has the author obtained results equal to those which follow the application of the direct current by way of the affected extremities and cervical (or lumbar) enlargement of the spinal cord.

If, however, the disease has reached the third stage and ulcers have appeared it is a good plan to apply diathermy to the hands. This aids the healing of the ulceration.

Chilblain (Erythema Pernio).

These respond quickly to local diathermy, but here again it is questionable whether the results are better than those obtained by the use of the sinusoidal or faradic currents. It is possible, however, that *general* diathermy, by its influence on the circulation and the whole body, may render the patient resistant to the etiological factors. A patient, known to the author, suffered severely from chilblains on the hands and feet every winter. The local application of diathermy caused them to disappear. General diathermy was then administered, and the treatment was

maintained over a long period until the cold weather came to an end. During the subsequent winters the patient was free from chilblains.

Acrocyanosis (Chilblain Circulation).

Cases of "chilblain circulation," cases with cold, blue extremities, with or without swelling, of the hands and feet, have been treated by diathermy, in the hope that the elevation of temperature of the affected parts might improve the circulation and restore the normal condition. This treatment has, in the author's experience, been ineffective. The skin assumes a red colour in place of the cyanotic hue, and the patient feels comfortably warm in the previously cold parts, but the blue colour returns in two or three hours, and the sensation of cold returns, though more slowly. Frequent repetition of the diathermy is always followed by the same degree of cyanosis and cold.

A case of acrocyanosis of the hand accompanied by excessive swelling and œdema in a female patient of 28, unmarried, was recently treated by intra-pelvic diathermy in order to ascertain whether the heating of the ovaries would influence the condition of the hand. No evident improvement, however, was obtained. It is possible that the application of diathermy to other endocrine organs, such as the thyroid or pituitary glands, might be successful.

Section VII

DISEASES OF THE ALIMENTARY SYSTEM

Good results have been claimed by certain investigators in the treatment of peritoneal adhesions, dilatation of the stomach with hypochlorhydria, cholecystitis and anal fissure, by diathermy. With the exception of the last-mentioned malady the author has received no cases of disease of the stomach or intestines or gall bladder for treatment by this method. Diathermo-therapy is, nevertheless, a rational procedure in the diseases mentioned. Heat can relieve pain, spasm and congestion. The experimental and clinical work of Lüdin showed that diathermy

could increase the peristaltic movements of the stomach. The movements of the stomach of a dog were recorded and their increase was shown during diathermy. The stomach of a human subject which had remained almost full, eight hours after taking a barium meal, was, on another occasion, subjected to diathermy, and found to be nearly empty four hours after taking the meal. On theoretical grounds, therefore, and by reason of experimental observation diathermy should yield good results in atony and deficient peristaltic movement of the stomach and intestines.

Atonic (primary) Dilatation of the Stomach.

To treat this disease by diathermy the patient should be in a recumbent posture. A metal electrode, measuring 6 inches by 8 inches, should be applied to the anterior aspect of the trunk so as to lie over the stomach. The directing electrode, a little larger in area, should be placed on the opposite aspect of the trunk. The current should attain a strength sufficient to procure comfortable warmth of the skin and it should be allowed to pass for thirty to forty-five minutes.

Good results have been described by Bordier and by Setzu.[1] The latter made analyses of the gastric contents, after test-meals, in a series of cases and showed that the free hydrochloric acid and the total acidity increased after diathermy.[2] On the other hand, Lüdin was unable to obtain an increase, but showed that the peristaltic movements of the stomach were amplified.

Peritoneal Adhesions.

Pain due to intra-abdominal adhesions after operation has been successfully treated by Nagelschmidt, Turrell, Iredell and other workers.

Plate electrodes should be placed over the site of the adhesions and on the back. Lengthy séances of thirty to forty-five minutes are advised.

[1] Setzu, *Riforma Medica*, Vol. 36, p. 125, 1920.

[2] The figures are quoted by Bordier in his work *Diathermie et Diathermothérapie*, 1st edition, pp. 424 *et seq.*

Hæmorrhoids.

Diathermy is an efficient form of treatment for the *pain* caused by hæmorrhoids. Some of the writer's cases remained free from pain for several months, and one patient, whose case is described below, was free from pain during the five years of subsequent observation. The treatment does not seem able to prevent prolapse or bleeding.

A suitable method of application is the following. An electrode identical with that illustrated in Fig. 51 is passed into the rectum and the circuit is completed by means of a belt electrode (Fig. 47, p. 148). The current should be strong enough to produce a comfortable degree of warmth. The thermometer should indicate about 105° F. Each application should last for twenty minutes and the treatment repeated twice weekly. The case which has been kept under observation for the longest period is that described below.

Male patient, aged 50. This patient suffered from prolapse in 1909. It was reduced. From 1911 to 1915 bleeding frequently occurred during defæcation. In February, 1917, the first attack of pain occurred, and extruding piles were noted. They did not disappear and were not replaced. From February, 1917, to June, 1919, there was constant aching pain. Frequent spasmodic pain was felt, not during defæcation, but during the latter part of the day. Defæcation did not cause pain.

On examination a number of firm fibrous pale hæmorrhoids were seen extruding from the external sphincter, and the mucous membrane was everted.

Diathermy was commenced on June 4th, 1919. Relief of the constant ache was noted at once, and the spasmodic pain became less frequent. On June 27th (after five applications) all symptoms had ceased. The patient reported at intervals since the cessation of the treatment and there was no recurrence during the next five years.

Colitis.

Three cases of colitis are now under treatment by diathermy in the Electrical Department of St. Bartholomew's Hospital. Two of these have improved in general health and the stools are less frequent and their consistency less abnormal. The treatment of these cases is in progress and further improvement is expected. In the third case, which has been under treatment for the longest time, the improvement is remarkable. The patient, a girl of 21, came for

treatment in the summer of 1926. She said that she had always passed frequent loose stools, and during recent months had passed nine or ten a day. She was pale and thin and her face was covered with the rash of acne vulgaris. Her menstrual periods had always been painful. She suffered from "train sickness" and needed the help of a friend to make the journey to the hospital. Diathermy was commenced and slow improvement took place, but she acquired influenza in the winter and relapsed. Treatment was recommenced in the spring. At the present time (March, 1927) her complexion is clear, the stools are normal and passed once only a day, and her dysmenorrhœa has ceased. She no longer suffers from train sickness.

This case was treated by general pelvic diathermy twice weekly. The active electrode was placed in the rectum and the circuit was completed by means of the belt electrode.

Anal Fissure.

The treatment of this painful affliction by diathermy is frequently successful. High-frequency currents, capable of producing diathermy, have been used for many years by French workers for the treatment of anal fissure, and cures have been reported in the large majority of cases.

The reasons for the success are doubtless the following. The diathermy lessens the contraction of the sphincter and probably abolishes the spasm of the muscle. The heat accelerates the blood supply to the region and aids the healing of the ulcer. Drainage of the latter is aided. This is shown by the fact that the patient notices moisture or exudation from the anal orifice after the treatment.

To conduct the treatment the patient should lie on his side. A belt electrode should be secured around the pelvis. The active electrode consists of a handle made of ebonite, to the end of which is attached a conical metal end-piece. The latter is lubricated with boracic ointment and its tip is pressed against the anus or, if the patient can tolerate it, introduced just within the sphincter. The current is started and slowly increased until the patient feels the sensation of warmth. Gentle pressure is maintained. After

two or three minutes the electrode will be felt to pass a little further within the sphincter. The current should then be increased, but no more than is sufficient to procure gentle warmth. The electrode should be passed as far as can be effected without pain. Directly any pain is produced the electrode should be partly withdrawn until the pain disappears. The current should pass for twenty minutes and the treatment be repeated daily.

Section VIII

Diseases of the Respiratory System

Pneumonia.

The treatment of pneumonia by diathermy was suggested by Dr. Byron S. Price [1] in 1916. It has been fully investigated, since January, 1922, by Dr. H. E. Stewart, of New Haven, U.S.A. In the hands of the last-mentioned worker remarkably uniform and good results have been obtained in cases of lobar pneumonia. In almost every case the temperature began to fall *by lysis* directly after the first application of diathermy to the affected lobe. The duration of the fever was not shortened, but while it lasted the pain and the characteristic expiratory grunt disappeared. In almost all the cases the cyanosis disappeared. The rate of resolution appeared to be accelerated.

The possibility of the extension of pneumonia to other lobes did not appear to be prevented by diathermy, but the treatment was equally successful in the newly involved lobes.

In a series of 47 cases treated by diathermy in U.S. Marine Hospital, No. 21, New York, the mortality was 17·1 per cent. In a series of control cases in the same hospital which were not treated by diathermy the mortality was 42·9 per cent. In a series of 22 private cases there was only one death. The youngest patient in this group was 15, the oldest 82.

Equally favourable results of the action of diathermy in lobar pneumonia have been reported by Dr. Broesker of New Jersey, and by Dr. Westervelt of Pittsburg.

[1] *American Journal of Electrotherapeutics and Radiology*, xxxiv, 445, September, 1916.

Those who are interested in the subject should consult Dr. H. E. Stewart's work, "*Diathermy, with Special Reference to Pneumonia*," published by Paul B. Hoeber, New York City. Particulars are given of 159 cases.

Other Diseases of the Lungs and Pleura.

A few cases of other diseases of the lungs and pleura in which diathermy appeared to have exerted a favourable influence have been reported by various authors. Nagelschmidt has recommended the treatment in *early* cases of pulmonary tuberculosis, and has noted disappearance of fever and a gain of weight. Diathermy is inadvisable in later cases on account of the risk of hæmorrhage.

Saberton states that he has had experience in one or two cases of tuberculosis of the lungs associated with pleural effusion in which diathermic applications appeared to have hastened absorption of the fluid.

Kowarschik and other Austrian and German workers have obtained good results in cases of chronic bronchitis and bronchial asthma.

The author has had no experience in the treatment of diseases of the lungs or pleura by diathermy. The part that diathermy will play in the future in these diseases and in cases which do not respond to other methods of treatment cannot be foretold at the present time. The same statement may be made concerning diathermy in diseases of the alimentary system. The chest is almost entirely the territory of the physician, and the abdomen is the territory of the physician and surgeon alike. Intimate and harmonious co-operation between the specialist in physiotherapy on the one side, and the physician or surgeon on the other, will be necessary for the discovery of truth in relation to diathermo-therapy in diseases of the abdomen and chest.

Section IX

DISEASES OF THE EYE

The temperature of the orbit and the contents of the orbital cavity can be raised by means of the diathermy current. The latter might, therefore, be useful in the treatment of certain diseases of the eye.

The author's experience is limited to two cases of gonococcal iritis. One of these was sub-acute and occurred in a woman who was the subject also of metastatic gonococcal infection of the joints. The application of diathermy to the orbit quickly removed the pain, and the treatment was completed by subjecting the primary focus of infection, *viz.* the cervix uteri, to the same agent. In the second case the iritis had been of long duration but was quiescent when the patient came for treatment. Arthritis was present and the feet were very painful. There was no complaint of pain in the eye, but the iris was adherent. The patient, a man of 30, was treated by applying diathermy to the prostate and vesicles and the parts which were secondarily infected, the object being to free the patient from infection before sending him to an ophthalmic surgeon for treatment of the adhesions. Iridectomy was afterwards performed by Mr. Foster Moore with successful results. No complication developed.

The author's method of applying diathermy to the orbit is the following. The active electrode consists of a slightly concave oval lead plate measuring 1 inch by $\frac{3}{4}$ inch. It is mounted on a wooden handle. The patient lies on his back with his head and shoulders supported. An indifferent electrode is applied to the back of the neck. This electrode is unnecessary if the patient lies on a condenser couch. The eyelids are closed and a pad of cotton wool is cut to the same shape as the lead plate of the active electrode but slightly larger. It should be soaked in strong salt solution and wrung out so that it does not drip. It should be $\frac{1}{4}$ inch thick. It is placed on the closed lids. The operator then places the active electrode in position so that the lead plate rests on

the pad. The current is started and gradually increased, a little at a time, until the patient feels a sensation of comfortable warmth in his eye. The operator holds the electrode in position while the current is passing. The duration of the treatment should be ten minutes.

CHAPTER XI

THE USE OF HIGH-FREQUENCY CURRENTS IN SURGERY

This chapter is divided into five main parts. Part I is introductory and shows the origin and development of the present-day methods of using high-frequency and diathermy currents in surgery. In Part II these methods are described in detail. In Part III the treatment of malignant disease in general by the diathermy current is described. Part IV deals with the treatment of malignant disease of special regions. In Part V the treatment of non-malignant growths and other forms of abnormal tissue by high-frequency and diathermy currents is described.

Part I

INTRODUCTION : HISTORY : PRESENT POSITION : TERMINOLOGY

Recent years have seen considerable activity in the use of high-frequency currents, not only for the *destruction*, but also for the *excision* of abnormal tissue. Currents capable of producing diathermy have been used for both purposes. During the past four years more attention has been directed to the use of special high-frequency currents for excising growths. These currents do not produce diathermy when used for the purpose of excision; in other words, they do not heat the abnormal tissue *en masse*. They form a film-like arc around the active electrode when the latter is inserted into the tissue, and the arc plays the part of a scalpel. In the treatment known as "fulguration" the high-frequency current destroys tissue by the production of sparks. Strictly speaking, this is not diathermy. Again, high-frequency currents are used for the production of heat within abnormal tissue, but the degree of heat, while sufficient to kill the abnormal part, is not high enough to cause coagulation. This form of treatment is known as "electro-desiccation."

The expression "surgical diathermy," as used by English authors, signifies the use of high-frequency currents for heating abnormal tissue through and through to a degree

high enough to coagulate it or boil the fluids within it. Workers in other European countries seem to use the expression in the same sense.

Since currents capable of procuring diathermy can also be used for excising tissue and for desiccating it, as well as for coagulating it, it is obvious that the expression "surgical diathermy," used in the sense stated above, is insufficiently inclusive. Further, it is inaccurate if it is used to connote the employment of high-frequency currents for the excision of tissue.

Before considering the question of terminology a brief account of the history and development of the surgical uses of high-frequency currents will be given. This will show the evolution of the methods which are employed at the present time.

History and Development of Surgical Uses of High-frequency Currents.—High-frequency currents were used in surgery before the importance of the heat which they could generate in the tissues was fully realised. The treatment took the form of directing sparks from high-frequency current generators on abnormal tissue. As far back as 1894 Oudin [1] described the destruction of benign tumours of the skin by sparks from the resonator attached to the d'Arsonval generator. (The Oudin resonator is well known to practitioners of electrotherapeutics. It is used to transform the current into another at higher voltage.)

In 1900, Rivière, of Paris, made a communication entitled "Action des courants de haute fréquence et des effluves du Resonateur Oudin sur certaines tumeurs malignes et sur la tuberculose" to the International Medical Congress held at Paris in the year stated. He used a method similar to that of Oudin.

In 1906, de Keating-Hart, of Paris, communicated to the International Congress of Electrology and Radiology at Milan a paper on the use of "*L'étincelle violente* contre le *vrai cancer*," and described the results which he had obtained during the previous year.[2] He used powerful apparatus

[1] *Bull. de la Soc. de Dermatologie*, August 3rd, 1894.

[2] Dr. de Keating-Hart employed the term "fulguration" as a name for the method which he adopted.

and longer sparks than those employed by Oudin and Rivière. In 1909 he published a monograph, "La fulguration et ses résultats dans le traitement du cancer d'après une statistique personelle de 247 cas."

In 1910, Doyen, of Paris, communicated to the Congress of Physiotherapy, held in the same city, a paper entitled "Traitement local des cancers accessibles par l'action de chaleur au-dessus 55°." He described two methods of employing high-frequency currents for destroying malignant tissue. In the first, which he termed "voltaisation bipolaire avec étincelles," the destruction was effected by sparks. A large metal electrode (indifferent) was applied to the patient and connected to one end of the resonator of a powerful d'Arsonval transformer. The active electrode terminated in a metal point. It was connected to the other end of the resonator. It was brought close to the tissue to be destroyed. Sparks of considerable intensity passed on to the tissue and carbonised the surface layers. Under the carbonised portion the tissue was destroyed to a slight depth.

In the second method Doyen connected the active electrode (a narrow disc) to one end of the solenoid of a powerful d'Arsonval transformer, and the indifferent electrode to the other end. The active electrode was placed *in contact* with the tissue to be destroyed. A current of considerable intensity was employed and the tissue was *coagulated* to a greater depth than in the first method. Doyen termed the treatment "electro-coagulation."

The realisation of the importance of the heat which high-frequency currents could generate in the body was followed, as shown in Chapter II, by the introduction of the so-called diathermy machine, constructed according to the suggestion of Nagelschmidt, of Berlin. It was shown by him that the current from this machine could heat the tissues to a degree high enough to coagulate and destroy them.[1]

The work of Nagelschmidt seems to have exercised more influence in establishing the present-day popularity of diathermy in surgery than the work of Doyen, although

[1] *Münch. med. Wochenschr.*, 1910, No. 50.

"electro-coagulation" is the same in principle as "coagulation of diathermy."

V. Czerny,[1] in 1910, directed attention to another method of using high-frequency currents in surgery. This method, known as the "arc-operation" ("Lichtbogensoperation"), had previously been the subject of experiment by de Forest. In this method the tissue is divided by the arc which surrounds the active electrode—a single needle—when the latter is brought into contact with and drawn through the tissue: at the same time the divided surfaces are coagulated. In this way abnormal tissue can be excised. E. Eitner[2] described a similar method in the same year.

The employment of high-frequency currents in this way, for the purpose of cutting, possesses the advantage that the minute vessels are sealed as they are severed. It did not at first receive the attention bestowed on the operation of coagulation by diathermy in which the diathermy current is used to destroy the abnormal tissue. During the past four years, however, it has been practised in this country by John Anderson,[3] and in America by George A. Wyeth, and further progress has been made.

In the United States the use of high-frequency currents for surgical purposes has received special attention and investigation. In 1907, F. R. Cook,[5] in an article entitled "The High-frequency Metallic Discharge; a New Treatment; its Possibilities," described the use of sparks from a high-frequency current generator for the destruction of enlarged tonsils, papillomata and other forms of abnormal tissue. In 1909, W. L. Clark,[6] a surgeon of Philadelphia, described a method which he had devised during the previous three years for the destruction of abnormal tissue by heat derived from high-frequency currents. In this method, which he termed "electro-desiccation," the heat is sufficient to destroy the tissue without causing actual coagulation.

[1] *Dtsch. med. Wochenschr.*, 1910, No. 11.
[2] *Wien. klin. Wochenschr.*, 1910, No. 5.
[3] Anderson has not yet published his method or results, but he has very kindly allowed the author to give the description which appears in later pages.
[4] *Amer. Jour. Electrotherap. and Radiol.*, N.Y., 1924, xlii. 186.
[5] *Med. Rec.*, New York, 1907, lxxii. 1017.
[6] *New York Med. Jour.*, 1911, xciii. 1131.

This method does not appear to have been adopted in Europe.

Coagulation by diathermy is practised in America. Preference is given to a method which procures coagulation *around* the abnormal tissue, at any rate, when the latter is a malignant growth. The growth is then destroyed or excised. For the purpose of excising abnormal tissue a special high-frequency apparatus has been devised by George A. Wyeth.[1] The current from this machine can play the part of a scalpel and, at the same time, seal the minute vessels as they are cut.

The use of the high-frequency current for cutting represents the latest advance in surgery.

High-frequency Currents in Surgery at the Present Day.—From the foregoing account it is evident that high-frequency currents can be used in various ways in surgery. The use of the diathermy current for the coagulation of tissue is only one of them. It is better, therefore, to discard the expression "surgical diathermy" and to include all the methods of utilising the heat derived from high-frequency currents for surgical purposes under the heading "ELECTRO-THERMIC METHODS OF SURGERY."

For the purpose of description these methods will be grouped as shown below. This will show the essential differences between them and the purposes for which they are used.

First method.—In this method the current generates heat by overcoming the resistance of the tissues, as in medical diathermy, but the heat is raised to a degree high enough to coagulate the tissue proteins.

This method is used for the following purposes, either (*a*) the coagulation of the abnormal tissue itself, or (*b*) the coagulation of the healthy tissue immediately around the abnormal part. In (*a*) the abnormal tissue is killed. This treatment will be called *coagulation by diathermy*, or *diathermic coagulation*. In (*b*) the abnormal tissue is not killed but imprisoned within a barrier of coagulated tissue. This treatment will be called "circumvallation."

Second method.—In this method the current generates

[1] *Loc. cit.*

heat on the same principle, but the degree of heat, while insufficient to cause coagulation, is high enough to kill the tissues by depriving them of water, *i.e.* by drying them.

This form of treatment is known as "*electro-dessication.*"

Third method.—In this method the current generates heat, but not by overcoming the resistance of the tissues. The active electrode is placed in close proximity to the tissue without actual contact. The intervening space is bridged, either by a rapid succession of sparks or an actual arc, according to the current employed.

The sparks are directed on the abnormal tissue. The cells are killed. Their death is due, in part, at any rate, to the heat of the sparks. The tissue is rendered hard and dry, whereas after diathermic coagulation it is relatively soft and moist.

This form of treatment is known as *fulguration.* When the arc is formed the active electrode can be introduced into the tissue and drawn along it; the arc precedes the electrode and divides the tissue. At the same time the divided surfaces are coagulated.

This method of cutting tissue was originally known as the "Lichtbogensoperation" ("arc-operation"). In its modern form it has been termed "treatment by the endotherm knife."

The three methods above described differ in regard to the *degree* and the *distribution* of the heat generated by the current. In coagulation by diathermy the heat need not attain a degree higher than that necessary to coagulate the tissue proteins, and in practice it does not exceed the boiling point of the tissue fluids. The heat is not restricted to one spot but is distributed throughout the abnormal tissue.

In electro-desiccation, as already mentioned, the heat does not reach the degree necessary for coagulation. It is distributed throughout the tissue requiring treatment.

In fulguration the temperature attained (by the sparks) is intensely high. This heat is produced *outside* the body and the temperature sinks to normal a short distance below the surface.

In the arc-operation the temperature attained in immediate contact with the active electrode is extremely high, but

it is restricted to a very minute area around the electrode. Neither in this operation nor in fulguration is the heat produced by overcoming the electrical resistance of the tissues. There is no diathermy.

Uses of Electro-thermic Methods in Surgery.—It is for the destruction and removal of new growths, both innocent and malignant, and infective granulomata that the electro-thermic methods are of high value. If they are coagulated by the diathermy current they are killed and the vessels are sealed. Infecting organisms are destroyed. These effects are obtained without disturbing the anatomical continuity. There is no cutting or scraping. In this way the risk of artificial metastasis and the dissemination of infection are avoided.

Cutting by the arc method is of particular value when malignant growths are to be excised, because the small blood vessels and the lymphatics are sealed as they are severed. Risk of dissemination is thereby reduced.

Fulguration possesses the same value as diathermic coagulation, but the depth to which it kills tissue below the surface is limited. On the other hand, the inflammatory reaction of the tissue in the vicinity is very slight. Fulguration is particularly suitable for non-malignant growths of the skin and mucous membranes, lupus nodules and vascular nævi of certain types.

Electro-desiccation is much used in the United States for the treatment of the conditions for which fulguration is employed in this country. It seems that destruction can be effected to a greater depth by electro-desiccation than by fulguration. This is an additional advantage.

A distinguishing feature of the electro-thermic method is seen in the character of the scar formed after the operation. Soft pliable unwrinkled scars are left and the cosmetic results are excellent. Another noteworthy feature is the slight local and general disturbance of the patient after the operation, even if a large mass of tissue is treated.

Terminology.—When high-frequency currents are used for heating a region of the body through and through, without damaging the tissues or impairing their vitality, the description of the treatment as "diathermy" is sufficiently

accurate. When the currents are used to heat a small portion of abnormal tissue through and through and coagulate it, the tissue-killing heat is restricted to the part to be treated, although some heat, insufficient to harm the tissues, is generated on the path of the current in the vicinity. Some workers prefer to call this treatment surgical "endothermy." The tissue to be killed, nevertheless, is subjected to diathermy; it is heated through and through, and since the heat is sufficient to coagulate, the treatment will be termed "diathermic coagulation."

A thin layer of healthy tissue can be coagulated around a malignant growth. Since the amount of tissue coagulated is very restricted the word "endothermy" would be more suitable than diathermy, but it would not convey information as to the site where the coagulation is produced. As this layer of coagulated healthy tissue is produced around a malignant mass in order to act as a protective rampart the operation will be called "circumvallation."

The division and excision of tissue by the arc produced by the high-frequency current is not, in any sense of the term, diathermy. Nor can it be called "endothermy," that is, if the word is used in the sense as stated above. Intense heat is restricted to a thin film around the active electrode, and the adjacent tissue is coagulated. George Wyeth uses the expression "treatment by the endotherm knife." Howard Kelly prefers to call the endothermy knife the "acusector." German workers, as already stated, used the expression "Lichtbogensoperation" (arc-operation). Since the production of an arc is essential the use of the high-frequency current for dividing and excising tissue will be called the *arc-operation*. "Endotherm knife" and "acusector" are names for the active electrode.

The expression "fulguration" was originally introduced to describe the destruction of tissue by sparks from high-frequency current generators. There seems to be general acceptance of the term for this purpose, and it will be used in this sense in the forthcoming pages.

The use of high-frequency currents to kill tissue by drying it, without coagulation, is generally known as "electrodesiccation," although Wyeth prefers to use the expression

"monopolar endothermy," because only one electrode is used. It is possible, however, to cause coagulation by using one electrode only. The word "desiccation" describes the changes produced in the tissue by this method and will be used in the following pages.

The various electro-thermic methods will be described in the following pages. Diathermic coagulation will be described first because it is most generally used in this country.

Part II

The Electro-Thermic Methods of Surgery

(1) Diathermic Coagulation of Abnormal Tissue

In this operation the abnormal tissue is destroyed by passing through it a diathermy current of sufficient intensity to coagulate it. The destruction is the result of the heat generated within the tissue along the path of the current.

Contrast between Coagulation by Diathermy and Cauterisation by Hot Metal.—In the use of the diathermy current for the destruction of tissue the heat is actually generated in the part to be destroyed, and the tissue can be coagulated *en masse*. On the other hand, when the heat is derived "ready made" from an external source (*e.g.* from a Paquelin cautery) its penetration below the surface is limited by reason of the poor conductivity of the tissues; the latter are coagulated to a slight depth only, even if the parts in contact with the hot metal are carbonised.

Fig. 53 (*a*) shows the limited extent of the cauterisation produced by Paquelin's instrument. The burner, which was 0·5 cm. broad, was heated and thrust 2·0 cm. into a piece of raw meat. The heating was kept up for twenty seconds. The tissue that was in contact with the burner was charred, while coagulation extended inwards for 2 mm. only. The same burner was then introduced—cold—for the same distance into another piece of meat and used as an electrode to lead the diathermy current into the tissue. Fig. 53 (*b*) shows that coagulation has spread much further

around, the distance being about 1·5 cm. below the end of the electrode, and about 1 cm. to each side. The cauterisation by the red hot platinum had burnt out a hole with charred blackened walls. The size of the hole was larger than the burner, so that the latter could be easily lifted out. When the diathermy current was used the tissue round the metal dried and adhered to the electrode. There was no charring, although the photograph gives this appearance.

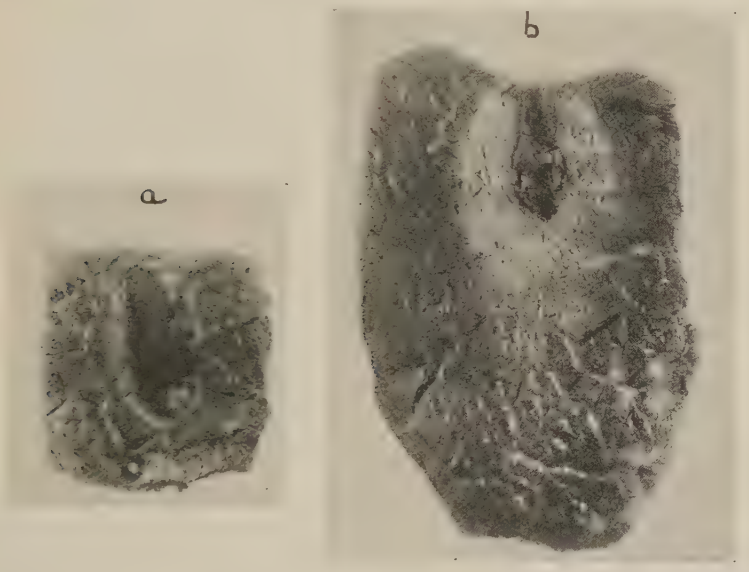


Fig. 53.—(*a*) Destruction of tissue by Paquelin's cautery. (*b*) Destruction by diathermy.

In diathermy the electrode is cold when it is placed on or in the tissues, and remains cold until it is heated from contact with the electrically-heated tissues. In the other methods of cauterisation by heat the cauterising metal is red hot before use, but cools down when introduced into the tissues. In these methods the heat is introduced from without and spreads within by conduction. In diathermy the heat is generated within the tissues. The former methods produce cauterisation by "epithermy," the latter produces coagulation by diathermy.

Coagulation by the diathermy current is also quite distinct from the destruction produced by electro-chemical methods. In the latter the galvanic current is used, and the destruction is produced by the caustic chemical bodies which accumulate around the electrodes. When describing the properties of the diathermy current it was mentioned that this current produced no chemical change in the body and no direct stimulation of the excitable tissues. A very much larger current can, therefore, be used for diathermic coagulation than for electro-chemical cauterisation, with a corresponding increase in the amount of tissue that can be destroyed.

Principles underlying Coagulation by Diathermy.—To coagulate tissue by the diathermy current a temperature of at least 60° C. is necessary. In the performance of the operation higher degrees of heat are often obtained and the tissue raised to a temperature of 100° C. or a little higher, at which the tissue fluids are raised to the boiling point.

To attain these temperatures the density or "concentration" of the current must be increased; in other words, its lines of flow must be concentrated in a narrow path. This is effected by reducing the area of *one* or of *both* electrodes. Thus, if an electrode of, say, one square centimetre in area is placed in contact with the abnormal tissue and the circuit for the current completed by applying another of, say, 200 sq. cm. to some distant part of the body, the density of the current will be very high in the region immediately under the small or *active* electrode, and very low in the vicinity of the large or *indifferent* electrode. The highest temperature will therefore be attained in the tissues in contact with the active electrode and the lowest in those which make contact with the indifferent electrode. The tissues in contact with the active electrode can be heated to 100° C. or higher, while those under the indifferent electrode are only slightly warmed. The temperature will progressively diminish as the distance from the active electrode is increased until, at a certain depth below this electrode, it will be insufficient to coagulate the tissues. The actual depth depends on certain factors which will be considered presently.

In certain circumstances the indifferent electrode may be

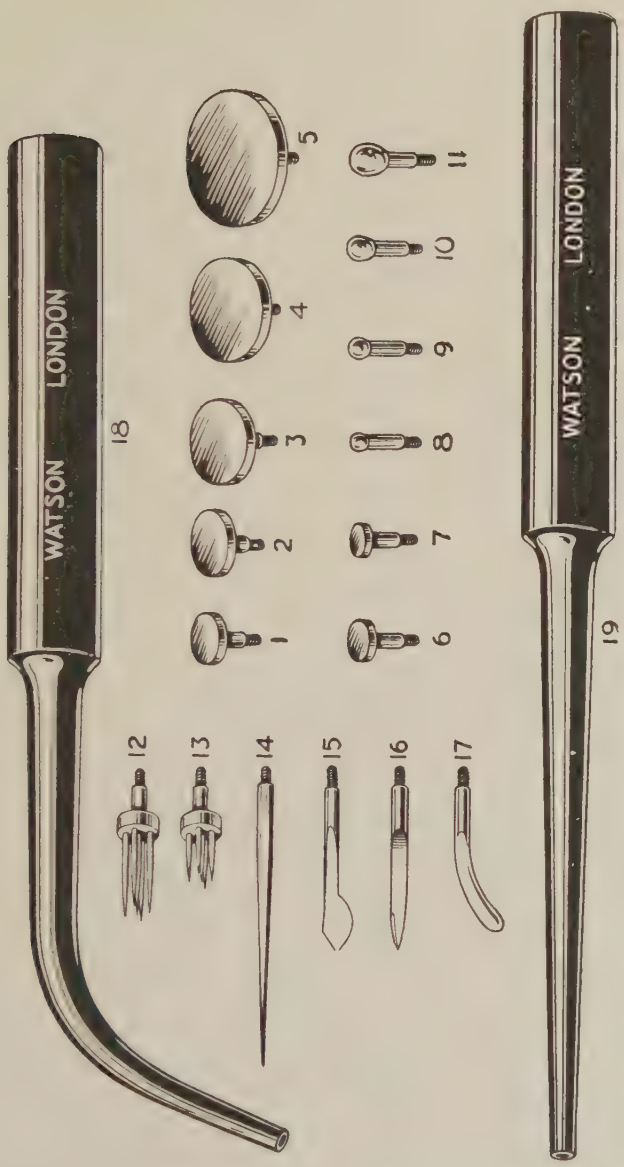


FIG. 54.—Active electrodes (Nos. 1 to 17) for diathermic coagulation. 18 and 19 are handles to which the electrodes are attached.

replaced by a second *active* electrode, both being placed in contact with the tissue to be destroyed. The current will then be confined to the tissue and its density will be high throughout its path. Two active electrodes may be used when the tissue to be coagulated projects well above the surface, as in the case of a fungating growth.

Electrodes.—The *indifferent* electrode consists of a sheet of pliable metal, such as lead, $\frac{1}{16}$ inch thick, with a terminal attached for connection to one of the cables from the diathermy machine. It should measure about 6 inches by 8 inches.

Various forms of *active* electrode are shown in Fig. 54 (Nos. 1 to 17). Nos. 1 to 7 are metal discs : the smallest has a diameter of 6 mm., the largest a diameter of 25 mm. Nos. 8 to 11 terminate in metal balls of various sizes. The largest has a diameter of 6 mm. No. 14 is a single-needle electrode : its length is 30 mm. Nos. 12 and 13 are multiple-needle electrodes. The needles are mounted on discs 8 mm. in diameter and are 12 mm. long in No. 13 and 18 mm. in No. 12. Nos. 15, 16 and 17 are blade electrodes.

Before use the selected electrode is attached to a handle. The latter is made of ebonite, and it may be straight, or curved at one end (Fig. 54, 18 and 19). The ebonite contains a metal core to conduct the current through. Into one end of the metal core the cable from the diathermy machine can be screwed. Into the other (narrow) end the active electrode is screwed. The ebonite projects beyond each end of the core, so that when the cable and electrode are in position there is no bare metal near the operator, the only uncovered metal being that which is to make contact with the tissue to be destroyed.

These electrodes and handles are suitable when the part requiring treatment and the process of the operation can be viewed. For the application of diathermy to the post-cricoid region of the pharynx, the œsophagus and the bladder and prostate special electrodes are required. These will be described later.

Experimental Coagulation of Tissue.—Those who have had no practical experience of surgical diathermy should perform some experiments on excised animal tissue, such as raw

meat. The events which occur when the diathermy current is passed through it, and the amount that is coagulated when different electrodes are used, can be seen. An idea can thus be gained of the extent to which the abnormal tissue is destroyed when similar operations are performed on the living subject.

A fairly large mass of beef should be obtained and placed on a metal plate measuring 6 inches by 8 inches. The plate should be connected by a cable to one of the terminals of the diathermy machine. It constitutes the *indifferent* electrode. An *active* electrode should be attached to the ebonite handle and placed in contact with the beef. The latter should be three or four inches thick. Thin pieces are unsuitable. A disc 6 mm. in diameter should be used as the active electrode for the first experiment. The current is now started and gradually increased. The following events take place.

The tissue in contact with the disc becomes gradually hotter until it coagulates. Coagulation begins *under the edge* of the disc. It spreads to the centre of the disc and below the surface. It then extends beyond the edge of the disc and now comes into view. A hissing sound is now heard. At first faint, it grows louder and steam begins to escape from under the disc. The fluid in the tissue under the disc now passes into a state of violent ebullition. The noise increases and becomes crackling in character owing to the appearance of sparks. The sparks pass from the edge of the disc over the coagulated tissue around the edge of the metal to the uncoagulated tissue beyond. If the current is continued or further increased the sparks increase in length and whiten the surface of the tissue for an increasing distance around the disc.

The reason for the appearance of the sparks is the *drying* of the coagulated tissue in contact with the disc. The tissue in this situation is deprived of all its fluid; it has, in fact, been "boiled dry." The dried tissue is a non-conductor, and the current passes in the form of sparks which dart from the edge of the disc to better conducting tissues beyond.

When this "insulating button" of dried tissue has formed,

sparks appear and further coagulation is now restricted to the surface of the tissue. Continuation of the current will not increase the depth of the coagulation below the surface except with extreme slowness.

If the current is stopped at the moment when sparks first appear and the tissue cut across vertically through the centre of the coagulated mass, the appearance will be similar to that shown in Fig. 55 at *a*. This shows that the

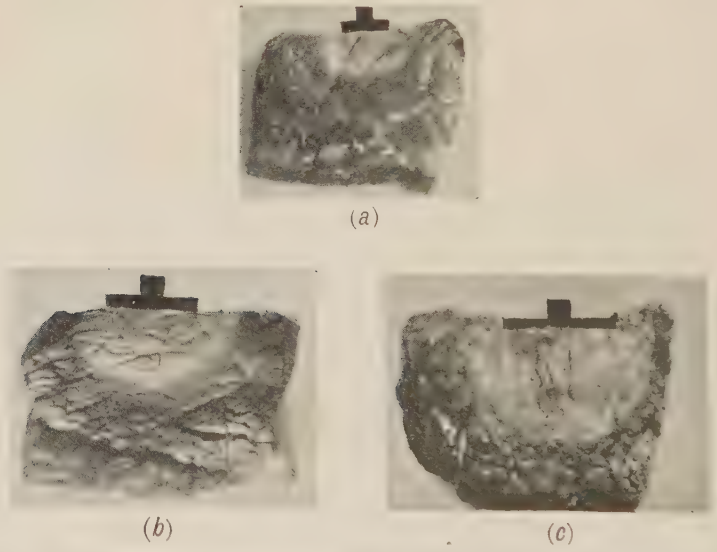


FIG. 55.—Masses of tissue coagulated when electrodes of different diameter are used. (*a*) Electrode 6 mm. in diameter. (*b*) Electrode 10 mm. in diameter. (*c*) Electrode 15 mm. in diameter.

coagulation had spread *below* the disc for about 6 mm., a distance equal to the diameter of the disc. It had spread *around* the disc for 3 mm. beyond the edge. The mass of coagulated tissue was rather less than a hemisphere in shape.

If discs of longer diameter are used and the experiments repeated, the events that occur are similar to those just described. The larger the disc the larger the mass of tissue that is coagulated, and the longer the time expended before sparks appear. In the experiments illustrated in Fig. 55, *b* and *c*, discs of 10 mm. and 15 mm. were used. The current

was increased from zero until sparks just appeared. The coagulation spread, in each experiment, to a depth equal (approximately) to the diameter of the disc.

If these experiments are repeated and the current *suddenly* applied at full strength, and not increased gradually from zero, it will be found that the coagulation will not extend to as great a depth. This is especially the case when small discs or large currents are used. The reason for this is the following. The diathermy current does not coagulate the tissue instantaneously; some of the heat is conducted away

FIG. 56.—Mass of tissue coagulated when a disc 20 mm. in diameter was used.

(though slowly), and it takes time to elevate the temperature to coagulation point. Now, if the current is suddenly started at the strength at which boiling appears, without gradually increasing it from zero to this strength, the sudden intense heat quickly dries a thin layer of tissue in immediate contact with the active electrode, and sparks appear before sufficient time has elapsed for the temperature of the deeper part to rise to coagulation point.

If, on the other hand, the experiments are repeated and the current increased *very slowly* from zero it will be found

that the coagulation will extend to a depth greater than the diameter of the disc. Very slow increase of the current delays the drying of the tissue in contact with the disc and allows time for the tissue at a greater depth to coagulate.

When discs of longer diameter than 15 mm. are used the current-density has a low value and the tissue in contact is heated slowly. For the reason just given the coagulation is likely to proceed to a depth greater than the diameter of the disc. Fig. 56 shows the amount of tissue coagulated when a disc of 20 mm. in diameter was used. It was not

Fig. 57.

until $3\frac{1}{2}$ minutes had elapsed that vigorous boiling occurred. Coagulation had then extended 25 mm. below the surface, *i.e.* 5 mm. more than the diameter of the disc.[1]

It may be concluded, then, that the use of large disc electrodes and the very slow increase of current (and heat) does not enable the operator to foretell the depth to which the coagulation will extend. On the other hand, the use of

[1] The tissue in contact with the disc electrode can be prevented from drying by allowing salt solution to drip around the edge of the disc while coagulation is proceeding. If sparks appear they can be quenched and the boiling stopped for a few moments by allowing a drop of the solution to fall. Boiling and sparking soon recur, but can be again stopped in the same way. In the deeper parts, however, the coagulation continues to spread, and it reaches a considerable distance. Fig. 57 shows the large mass of tissue that was coagulated when the machine was giving its maximum current and drying was prevented by salt solution. The disc electrode measured 6 mm. in diameter.

discs not larger than 15 mm. in diameter, and the increase of the current from zero to the value at which the sparks are first seen (a few seconds being occupied in the increase), will cause the coagulation to proceed to a depth equal to the diameter of the electrode.

The reading of the amperemeter gives no information of practical value regarding the extent or depth of coagulation.

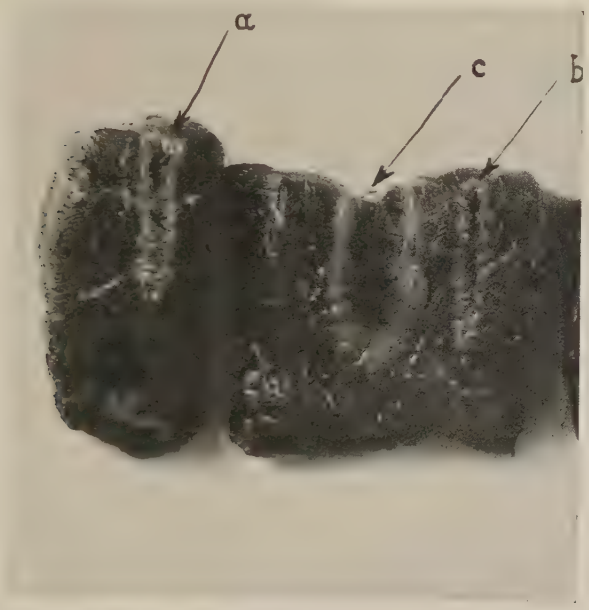


FIG. 58.—Masses of tissue coagulated with single-needle electrode. (*a*) When current was increased at the same rate as in the other experiments. (*b*) When current was started at once at full strength. (*c*) When current was continued for a time after sparks appeared.

If a single-needle electrode, like that shown in Fig. 54 (No. 14), is used and thrust into the tissue for, say, 2 cm., the coagulation will commence *at the point* of the needle and spread upwards around its shaft until it reaches the surface of the tissue. By the time it reaches the surface, or a little before, the sound of ebullition will be heard. If, now, the current is stopped and the needle withdrawn, the coagulated mass can be seen by cutting the tissue along the line formerly occupied by the needle. It is cylindrical in form and surrounds the needle like a sheath (Fig. 58, *a* and *b*).

If the current is allowed to flow for a longer time before withdrawing the needle there will be scarcely any further spread of coagulation beyond the point or sides of the needle. The reason for this is the drying of the tissue in contact with the needle and its conversion into an insulating sheath. Just as the coagulation starts at the point and proceeds up the shaft to the surface of the tissue, the drying begins in the same region and follows the same direction.

If the needle remains in position until the tissue in contact is dry, and then withdrawn, it will bring with it portions of tissue tightly adherent to its surface. If, however, it is withdrawn at the moment when the tissue around is coagulated and before it is dried, it will come away clean and bring no tissue with it.

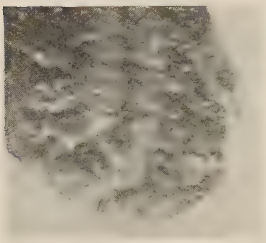


FIG. 59.—Mass of tissue coagulated around a single needle when current was very slowly increased.

It has already been shown that the *rate of increase* of the current influences the extent of spread of coagulation when disc electrodes are used. The same is true when single-needle electrodes are used, but the influence of the rate of increase is very much less. The area of contact of tissue and metal is very small and the current, in consequence, is highly "concentrated." Coagulation and drying are quick. In Fig. 58 (*b*) the coagulation extended 1 mm. around the needle; the current was applied suddenly at full strength. In Fig. 58 (*a*) the current was started at zero and a few seconds were occupied before coagulation reached the surface; coagulation spread for 2 mm. around the needle. In Fig. 59 the coagulation had spread 4 mm. around; the current was very slowly increased, three minutes being occupied before it reached its maximum.

If the needle is allowed to remain in position and the current maintained or increased for a time after the tissue in contact with the metal has dried, sparks will pass from the point and sides of the needle through the dried sheath, and slowly char it. At the same time the tissue immediately beyond will be coagulated to a slight additional distance.

This, in its turn, will be dried and charred. In this way it is possible, by means of the needle electrode, to burn out a cavity. But even if this is done the coagulation will not extend for more than a slight distance into the tissue lining the cavity. This is illustrated in Fig. 58 (*c*); a cavity has been produced, the tissue having been burnt away by the long-continued passage of sparks. After a time the needle was moved around the wall of the cavity. Coagulation did not extend for more than 3 mm., however, into the tissue lining the wall.

If multiple-needle electrodes like those shown in Fig. 54

FIG. 60.—Tissue coagulated around multiple-needle electrodes.

(12, 13) are used the coagulation spreads to a greater distance below and to each side. It begins at the points of the needles and spreads up and around the shafts. The tissue coagulated in Fig. 60 (*a*) extended 17 mm. below the surface. The electrode used was a disc 10 mm. in diameter, bearing five needles, each being 6 mm. long. The current was increased from zero until vigorous boiling occurred and sparks appeared at the edge of the disc. In Fig. 60 (*b*) the coagulation spread for 27 mm. below the surface. The disc bore five needles, each being 12 mm. long. It will be noted that the coagulation spread, in each experiment, a considerable distance below the points of the needles. The distance was much greater than would have been the case if a single needle had been used. The reason is the following. With the multiple-needle electrodes the area of contact of

metal and tissue is considerably increased; the current density is relatively low and the heating slow. Consequently there is time for the coagulation to spread further before the tissue is dried.

For this reason the operator cannot foretell the distance beyond the points to which the coagulation will spread with the certainty that is possible when the single-needle electrode is used.

Coagulation of the Living Tissues by the Diathermy Current.—When the living tissues are coagulated the events which occur are similar to those already described. The tissues around and under the active electrode acquire pallor from coagulation. Steam escapes and boiling occurs. Finally, the tissue in contact with the electrode dries and sparks make their appearance. The distance below and around the electrode to which the coagulation extends is influenced by the shape and size of the electrode, as in excised tissue. It is also influenced by two additional factors, *viz.* the movement of the blood, and the degree of moisture of the tissue.

The blood removes, by convection, some of the heat generated by the current. This has the effect of preventing coagulation in the region where the heat would, in non-vascular tissue, be just sufficient to cause it. For this reason the coagulation does not extend so far below or around the electrode in living tissues. On the other hand, it must be remembered that cells can be deprived of their vitality and life by heating them to a temperature insufficient to coagulate their protoplasm.[1] Further, the lethal temperature for malignant cells is lower than that for normal cells. It must be concluded, therefore, that tissue is destroyed for a little distance beyond that to which actual coagulation proceeds. Under the electrode (after coagulation is complete and sparks appear) the destroyed tissue may be divided into four zones or strata (see Fig. 61). In contact with the electrode the tissue is coagulated and completely dried. This is the "insulating button." Under it the tissue is coagulated but not dried: the cells are destroyed and the vessels and their contents coagulated.

[1] The treatment known as "electro-desiccation" causes the destruction of abnormal tissue by heating to a degree which deprives it of its fluids. This is described on p. 248.

In the next stratum the cells and the vessel walls are coagulated but not the blood. The latter moves through the heated part and passes out of it before sufficient time has elapsed for it to coagulate.[1] The temperature in this stratum is only high enough to coagulate the non-moving parts. Beyond this stratum the temperature, while insufficient to coagulate, is high enough to deprive the cells of their fluid and exert a lethal action on malignant tissue.

If the disc electrode is placed in contact with skin the coagulation will not proceed more than a slight distance below the surface, because the epidermis, a relatively dry

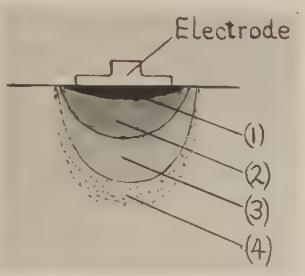


FIG. 61.—Diagram to represent the zones into which the tissue may be divided when killed by diathermy.

tissue, is soon rendered completely dry and non-conducting. The same is true of bone. The periosteum dries very quickly and sparks appear almost at once.

These facts render it difficult to judge the depth to which the tissues will be killed when disc electrodes are used. As an approximate guide, however, it may be taken that the depth of destruction, in the case of moist soft vascular tissue, is equal to the diameter of the disc when the current is increased until sparks appear.

The depth to which the living tissues are destroyed by the diathermy current is much more under the control of the operator when single-needle electrodes are used. Whether the tissue is moist or relatively dry, and whether it is highly vascular or otherwise, the depth of destruction is determined by the depth of insertion of the needle.

[1] This fact is very important and is the reason, as will be shown later, for the so-called "secondary" hæmorrhage that may occur, in certain cases, after the operation of diathermic coagulation.

Although the destruction *around* the needle does not extend far, it is easy, by repeated insertion, to coagulate to any desired extent. When the needle is used for coagulating abnormal tissue the destruction will not extend for more than two or three millimetres around the shaft or below the point.

Subsequent Changes in Region subjected to Diathermic Coagulation. — Tissue which has been coagulated by diathermy forms a slough which slowly separates from the healthy surrounding parts. Granulation tissue fills the residual cavity and epithelium grows over. The granulations are converted into scar tissue. The latter does not contract nor does it form adhesions with parts which may be in contact. The inflammatory reaction of the tissues around the coagulated part is slight.

Effects of Diathermic Coagulation on Patient.—These will be considered in more detail when the treatment of malignant disease is described. It may be mentioned here, however, that the coagulation, even of large masses of tissue, and the subsequent sloughing produce a surprisingly small amount of disturbance. Shock after the operation is absent and the subsequent discomfort, local and general, is slight.

Performance of the Operation on the Patient.—The selection of the electrodes and the details of the procedure differ according to the nature, size and situation of the abnormal tissue. The treatment of malignant disease is described in Parts III and IV, and that of non-malignant disease in Part V. These parts are subdivided, and the treatment of disease in different regions is described under separate headings.

(2) Circumvallation

The name " circumvallation " has been given by Howard Kelly to the coagulation of the *healthy tissue around* an abnormal part. In this way the latter can be isolated from its surroundings.

By repeated insertion of the needle into adjacent parts of the tissue—the directions of insertion being parallel on

each occasion—and coagulation of the tissue around it is possible to produce a wall of coagulated tissue. If the coagulation extends for 2 mm. around the needle it should be inserted successively at points 4 mm. from each other in order to secure an uninterrupted wall of coagulation. The wall can be made cylindrical if desired. The length of cylinder will correspond to the length of insertion of the needle. It is also possible to make the wall the shape of a hollow cone, its rim being on the surface of the tissue, and its apex at the desired depth below. This can be done by inserting the needle obliquely at different points along the circumference of a circle (which will be the rim of the cone) to a common point (which will be the apex of the cone). When this is done the tissue within the wall of coagulation will be shut off from that outside.

The object of circumvallation is to provide an isolating wall or rampart around a malignant growth, and minimise or prevent the risk of artificial metastasis when the growth itself is removed or a portion excised for histological examination. In itself, circumvallation is not sufficient for the treatment of malignant disease.

(3) Combination of Coagulation with Cutting by the Knife

When abnormal tissue is coagulated it is left to separate spontaneously. If the coagulated part were excised there would be considerable hæmorrhage, because the heating of the tissues in the vicinity causes a large increase of their blood supply. The object of the operation about to be described is to excise the abnormal part, the surrounding healthy tissue being coagulated and, at the same time, cut through.

The blade electrodes shown in Fig. 54 (16 and 17) may be used for this purpose. A demonstration of the process can be made on raw meat. The blade is inserted and the current increased until the tissue has coagulated around it. It is then moved forward in the direction of the cutting edge. The rate of movement must be slow enough to allow coagulation to proceed in advance of the edge, so that

coagulated tissue alone is cut. The appearance of tissue coagulated and cut in this way is shown in Fig. 62 (*a*). The blade used was 2 mm. wide.

When this operation is performed on the living subject the vessels are cut as well as the tissue around them. If the blood is not coagulated by the heat before the vessels are severed it will escape. Loss of blood is a serious disadvantage. It obscures the field of operation and is difficult to stop, because the heat generated by the current lessens the viscosity of the blood, accelerates its flow and increases

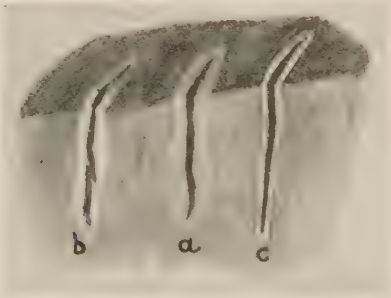


FIG. 62.—Tissue cut by electrothermic methods. (*a*) Appearance after the combined coagulating and cutting method. (*b*) and (*c*) Appearance after dividing part of the tissue by the "arc method." (*b*) was obtained by use of a current of unsustained oscillation and relatively high voltage. (*c*) was obtained by using a current of sustained oscillation at a relatively low voltage. For description of the "arc method" see p. 239 *et seq.*

its supply. But there is a more serious risk when malignant tissue is being treated. If bleeding occurs and the cells have not been destroyed there is the likelihood of producing metastasis.

When the operation above described is performed for the removal of tissue it is really a combination of circumvallation and excision. The part which is to be removed is surrounded by a wall of coagulated tissue and the wall is divided into two layers as fast as it is formed.

It requires considerable practice to perform this combined operation without loss of blood. It is in the region of the point of the blade that capillaries and lymphatics, or larger vessels, are liable to be cut before their contents are

coagulated. The operator cannot see the extent of the coagulation except on the surface, and it is easy, when moving the blade forwards, to press its point into uncoagulated tissue. For this reason it is advisable to perform an additional circumvallation by means of the single-needle electrode before using the blade. This will be an additional and more complete safeguard against metastasis. After the wall of coagulation has been formed in the healthy tissue adjacent to the growth, the blade electrode should be introduced and the excision effected just within the wall.

A more efficient method of excising a malignant growth after circumvallation is described on p. 239, under the heading "Use of the High-frequency Current for Cutting."

(4) Combination of Coagulation with Removal by Snare

This method resembles that described above, but a wire loop is used as an active electrode in place of a blade. It is used for the removal of pedunculated growths without loss of blood. The loop, attached to a special holder, is placed around the pedicle so as to grasp the latter around its base. The current is started and increased until the tissue in contact with the loop whitens from coagulation. The loop is now slowly tightened and the wire drawn through the pedicle until the latter is severed.

By this operation the vessels which supply the growth are sealed while they are severed by the wire, and the divided surfaces of the pedicle are coagulated to a slight depth.

A snare electrode for use with the diathermy current has been devised by E. Broughton Barnes, of Northampton, and used by him for the removal of growths of the naso-pharynx. It is illustrated in Fig. 74. Another model of snare electrode, known as the "anse diathermique," has been introduced by Dr. Bordier, of Lyon.

(5) Fulguration

Definition.—Fulguration is a method of treatment in which abnormal tissue is killed by means of the heat derived from sparks.

Contrast between Fulguration and Coagulation by Diathermy.—In the operations already described the diathermy current is passed through the tissues; its path is concentrated in the part to be destroyed, and heat, sufficient to cause coagulation, is generated within and along the tissue to be destroyed. If the active electrode is placed, not in direct contact with the tissue, but at a short distance from it, the current will bridge the intervening air space in the form of thick sparks. The tissue on which the sparks fall is almost instantaneously whitened on the surface, and it looks as if it were coagulated. As the sparks continue to pass, the whitening proceeds slowly below the surface.

The treatment of abnormal tissue by directing sparks upon it is known as "fulguration." It differs from diathermic coagulation in the following ways. The current generates heat by overcoming, not the resistance of the tissue, but that of the air in the space between the active electrode and the tissue. In overcoming the air resistance it forms sparks; in other words, it heats the air to incandescence. The tissue is rendered hard and dry by fulguration, whereas it remains relatively moist and soft during diathermic coagulation. It is rendered much whiter by fulguration than by diathermic coagulation, although if the passage of the sparks is continued for a sufficient time it darkens and chars. The drying and hardening due to fulguration are quickly produced, but do not extend far below the surface. On the other hand, the coagulation produced by the diathermy current takes place more slowly, but can be made to extend for a much greater distance below the surface.

Generators used for Treatment by Fulguration.—Fulguration was originally performed by currents supplied at very high voltage. They were derived from resonators of the Oudin type attached to the d'Arsonval generator. American workers combine a small resonator of the Oudin or Tesla type with a diathermy machine, and obtain long and thick sparks. In this country the diathermy machine is used without a resonator. Short thick sparks are obtained. Dr. Turrell, of Oxford, was the first, in this country, to use the modern diathermy machine for fulguration. The

original d'Arsonval generator or the modified form may also be used.

Demonstration of Fulguration.—Fulguration can be demonstrated in the following way. A block of meat is placed on a metal plate, and the latter is connected to one of the terminals of the diathermy machine. A single-needle electrode is connected to the other pole. The machine is set in operation and the point of the needle is brought close to the meat. When it is sufficiently close a torrent of sparks will bridge the gap. The length of the sparks depends on the adjustment of the machine. The meat quickly whitens and dries at the spot on which the sparks fall. At first the drying is superficial, but as the sparks continue to pass it proceeds for a certain distance below the surface. At the same time the superficial part darkens and is eventually carbonised. In this way portions of tissue can be converted into hard dry masses.

This may be termed the "direct" method of performing fulguration. The "indirect" method is the following. It is usually adopted when the operation is performed on the living subject. The meat is placed on the ebonite top of the condenser couch (Fig. 44, p. 131) and connected by a wire to one of the terminals of the diathermy machine. The other terminal is connected to the metal plate under the ebonite. The machine is set in operation. If, now, a pointed metal rod is brought close to the meat, without making actual contact, a rapid succession of sparks will bridge the gap. The meat will undergo the changes already described. If the machine is adjusted so as to give a weak current the point of the electrode must be placed very close to the meat before sparks will pass. The gap can be widened, and longer sparks applied, if the machine is regulated so as to give a stronger current. The maximum length to which they can be increased depends on the design of the diathermy machine. Those which are constructed so as to yield currents at higher voltage enable the operator to apply longer fulgurating sparks, and the latter may attain a length of a quarter of an inch.

During the operation the following electrical changes take place. The block of meat is charged alternately positively

and negatively, the polarity changing with the same frequency as that of the current provided by the diathermy machine. These charges pass, in part, to earth, by way of the metal rod which is grasped by the operator, and they bridge the gap between the meat and the metal in the form of sparks. The electrode is earthed when held by the operator. It can be more efficiently earthed by connecting it to a water pipe or tap. The sparks will then be thicker and the tissue more quickly dried.

The Operation of Fulguration on the Living Subject.— Fulguration can often be performed on adult patients without procuring general or local anæsthesia. Children may require a local anæsthetic. In the case of infants a general anæsthetic is necessary. The patient sits or reclines on the condenser couch. The metal plate under the couch is connected to one of the terminals of the diathermy machine. The other terminal is connected, by means of an insulated cable, to an electrode which is applied to the patient. In the case of adult patients this electrode should be a metal rod and it should be grasped in the hands. In the case of nervous children and infants the electrode should be a metal plate, and it may be applied to the leg.

The machine is set in operation and adjusted to give a weak current. The operator holds a pointed metal rod or wire (the operating electrode) and brings it near the tissue to be fulgurated until sparks pass on to it. Any pointed metal object, such as a hat-pin, or a piece of wire with a sharpened end, may be used as an operating electrode.

Very short sparks should be applied at first so as to dry a thin superficial layer of tissue. The sparks should then be made a little longer so as to dry a thin underlying layer. The process is repeated until the tissue has been dried to the desired depth. When the superficial layers are dried the point of the electrode may be placed in contact. The sparks will perforate the dried layers and dry the underlying tissue.

The operator must not touch the skin of the patient while the machine is in operation, either with the hand which holds the electrode or with the other hand. Sparks will not pass between the tissue to be treated and the point of

the electrode if he makes contact. If he makes momentary contact there will be a passage of sparks between him and the part of the patient which he touches. This disturbs the patient and may damage his skin. When very exact localisation of the treatment is required the operator may steady the hand which grasps the electrode by resting it on an ebonite rod. He may hold this rod in the unoccupied hand and support the other end on the patient or some convenient object.

During some experiments on fulguration the author found that longer and thicker sparks could be obtained if the operator sat on the condenser couch on which the patient rested. There must be no contact between the patient and the operator. This method is useful when the diathermy machine does not yield current at high voltage.

Subsequent Reaction.—Very slight inflammatory reaction follows fulguration, and if the amount of tissue treated is small it is not apparent. There is little exudation of fluid. In this respect fulguration differs from diathermic coagulation. After the latter there is a free exudation of lymph and it may persist for several hours. The fulgurated tissue gradually forms an adherent scab. After the latter has separated a soft pliable scar is left. It does not contract. The patient rarely suffers discomfort after fulguration. In some cases serum collects under the scab and causes pain, but relief may be obtained by raising the edge of the scab and allowing the serum to escape.

(6) Use of High-Frequency Currents for Cutting

("Lichtbogensoperation"; arc-operation; cutting by the endotherm knife.)

Principle.—In the operation now to be described the electrical energy of the current is mainly used, not for heating the tissues along its path, but for the production of a minute arc. This arc is formed between the active electrode (a single needle or narrow blade) and the tissue into which it is inserted. There is no diathermy. There is no perceptible heating of the tissues along the path of the

current. Heat is produced where the active electrode is in contact with the tissue, but there is no generation of heat in the tissues away from the electrode.

Experimental Cutting of Tissue.—Place a block of meat on a metal plate and connect the latter to one of the terminals of a diathermy machine. Connect a single-needle electrode to the other terminal and bring its point very close to the meat. Adjust the coupling handle so that the machine will give its maximum or nearly its maximum output when the switch is turned. Now set the machine in operation. A torrent of sparks will pass between the point of the needle and the meat. If the gap is quite narrow the sparks will pass without apparent intermission and give the appearance of an arc. If, now, the needle is passed into the tissue it can be moved forward and made to divide the meat like a knife. It will be noted that the divided surfaces present the same appearance as the tissue on which the sparks fell just before the needle made contact. They are whitened as if coagulated. Considerable sparking and spluttering occur as the tissue is divided, especially if the machine supplies current at high voltage. The depth to which the coagulation proceeds in the divided surfaces and the ease with which the tissue can be separated by the active electrode depend on the current which is employed. If the oscillations are sustained and undamped, and the current supplied at a relatively low voltage, the tissue can be divided with the greatest ease and the depth of the coagulation of the divided surfaces will be less than a millimetre. A current of this kind can be used for cutting operations. It can play the part of a scalpel and, at the same time, seal the minute vessels as it divides the living tissues.

Of the machines described in Chapter V, that which fulfils the requirements above-mentioned is the portable model constructed by Schall, for connection to a source of *direct* current, such as a D.C. main [1] (see p. 50 and Fig. 21).

The experiment above described should now be repeated, and the Schall portable model used in place of the usual type of diathermy machine fitted with a spark-gap. A

[1] This machine produces sustained and almost undamped oscillation.

single needle or a narrow blade, not more than two millimetres in width, should be used as an active electrode. The machine is set in operation and adjusted to give its maximum current. The active electrode is now brought into contact with the tissue. Just before it touches the latter a minute arc appears at the spot where the point of the blade makes contact with the tissue. The blade is now thrust into the tissue and drawn across it as in making an incision. It encounters no resistance as it is moved forward, and the tissue seems to separate of its own accord on each side of the advancing blade. If now the separated surfaces are examined they will be seen to present the appearance of coagulated tissue. The depth to which the coagulation has proceeded is slight. On the surface of the tissue it can be seen as two white lines, one on each side of the line of incision.

The division of the tissue and its coagulation are caused by the film-like arc which surrounds the blade electrode. As already mentioned, a minute arc appears at the point of the blade just before the latter touches the tissue. As the blade enters the tissue it does not make actual contact with the latter, but is separated from it by a film of incandescent air, or arc. As the blade is moved forward the arc accompanies it and cleaves the tissue; at the same time it causes the coagulation of the divided surfaces.

In this operation the sole function of the blade is that of one of the electrodes for the production of an arc. The tissue immediately around the blade acts as the other electrode. In moving the blade the operator merely guides the arc. He does not cut the tissue, and he feels no sensation of resistance as he moves the blade forward.

The depth to which the coagulation proceeds on each side of the blade depends on the rate of movement of the latter and on the adjustment of the diathermy machine. If the blade is moved rapidly the coagulation will proceed no further than a small fraction of a millimetre. If it is moved slowly it will extend to a somewhat greater depth, but not more than about a millimetre. This is the case if the machine is adjusted so as to give its maximum current, with the oscillator and resonator tightly coupled. If they

are less tightly coupled the coagulation will not proceed to as great a depth.

If the blade is allowed to remain stationary for more than a moment the arc will begin to char the tissue in immediate contact. The carbonisation will slowly extend if the arc is not moved, and a little cavity will be burnt out.

If the blade is moved with extreme rapidity the arc will be extinguished. The blade will now cut the tissue mechanically just as a scalpel cuts it. Although the current will be passing, the movement of the blade will prevent the accumulation of heat and the temperature will not rise high enough to cause coagulation.

If, now, the blade is stopped there will be a rapid rise of temperature around it, and coagulation will take place. *Slow* movement of the blade will now cut the coagulated tissue, and if it is again brought to a stop the tissue in contact will dry and sparks will pass between the blade and the dried tissue.

A demonstration of various electro-thermic methods can be made by proceeding in the way described above. First, cutting with the arc. Second, the extinction of the arc and cutting with the knife. Third, the coagulation of the tissue around the blade (diathermic coagulation). Fourth, the cutting of the coagulated tissue (combined coagulation and cutting). Fifth, the sparking of the tissue around the blade (fulguration).

Changes in Tissue effected by the Arc.—The tissue in contact with the arc almost instantaneously whitens. It presents the same appearance as tissue on which sparks have been directed for a few moments. It is paler than that which has been subjected to diathermic coagulation. Coagulation by the diathermy current, as already mentioned, is a relatively slow process; the temperature attained by the coagulated tissue does not exceed the boiling point, and relatively large masses of tissue are coagulated. The momentary exposure of tissue to the intensely high temperature of the arc or sparks seems to *dry* the tissue proteins as well as coagulate them, both processes being effected simultaneously and instantaneously.

The histological appearance of tissue cut by the arc is

described on p. 251. The macroscopic appearance is shown in Fig. 62 (*b*) and (*c*).

Contrast between use of High-frequency Current for Cutting and for Coagulation.—It must be realised that when the current is used to produce an arc within the tissue it is not a diathermy current. The electrical energy is utilised almost entirely in producing the intense localised heat of the arc. Although some current must pass along the circuit it is insufficient to heat the tissue appreciably in the parts that are not in contact with the arc. When cutting with the arc the amperemeter needle moves scarcely at all from zero.

On the other hand, when no arc is formed the energy of the current is largely expended in heating the tissue by overcoming its resistance. The tissue coagulates where the current is concentrated and the amperemeter needle moves some distance away from zero.

Division of Living Tissue by the Arc Method.—When the living tissues are divided by the arc the minute vessels are sealed and there is no escape of blood or lymph. If larger vessels are severed hæmorrhage occurs. The cut ends can be sealed by employing the current to procure *diathermy*. They are seized with pressure forceps and the blade electrode is placed in direct contact with the latter. The forceps now acts as an active electrode. The compressed ends of the vessels are coagulated by the heat and sealed.

At the moment when the electrode touches the tissue and the arc forms, the muscles in the vicinity twitch. They do not contract, however, when the electrode and arc are within the tissue or moved along it. The reason for this stimulation is uncertain. When an alternating current sparks across a gap between a point and a plate it is partly rectified, that is, the major portion travels in one direction only. At the operation the surface of the tissue acts as a plate and the tip of the electrode as a point. The current, therefore, is partly rectified at the moment when the point of the electrode is almost in contact with the tissue, and the muscles are momentarily stimulated. When the electrode is passed into the tissue there is no point-plate gap and no rectification. Therefore there is no stimulation. This explanation has been suggested by Prof. Hopwood.

The Employment of the Cutting-current in Surgery.—The latest advances in the use of the cutting currents in surgery have been made by John Anderson, of Dundee, and George Wyeth, of New York. Both surgeons have obtained considerable experience and have employed currents which are more suitable for the purpose than those which were used by Continental workers. It is probable that these currents will be more widely used in the future, particularly in the surgery of malignant disease. For this reason the work and methods of the surgeons above named will be described in brief.[1]

Apparatus.—After experimenting with various machines Anderson found that the portable model of Schall provided the best cutting-current. As already mentioned, this machine gives a current of almost undamped oscillation. Wyeth had a special machine constructed. It yields a current which differs, in certain respects, from that used by Anderson. The frequency of the oscillation is extremely high, *viz.* five millions per second, whereas that of the current from the Schall portable model is 350,000 per second. Wyeth's current does not produce diathermy; there is no coagulation around a needle electrode when the current is started *after* the insertion of the needle into the tissue. If, however, the needle is brought into contact with the tissue, *after* the current is switched on, an arc will form and the tissue can be divided. The depth to which the coagulation proceeds is very slight and can be reduced to one-tenth of a millimetre. The current can, therefore, be used for dividing tissue in near vicinity of important structures.

The current from Schall's machine, on the other hand,

[1] The author is indebted to George Wyeth and Howard Kelly for demonstrations of the method in their clinics at New York and Baltimore, and for much useful information on the subject. He is likewise indebted to John Anderson for valuable information regarding his methods and results. Inspired by the work of these surgeons the author has worked with a current resembling that used by Wyeth, and provided by an experimental machine constructed for the purpose by A. E. Dean. These cases, which include one of a carcinoma of the floor of the mouth, another of carcinoma of the tongue, and one of a growth (probably an early rodent ulcer) on the *ala nasi*, were treated too recently (November, 1926, January, 1927, February, 1927) to enable any statement to be made regarding permanency of results.

will cause coagulation if the current is started *after* the active electrode is placed in contact with the tissue.

As an active electrode Anderson employs a narrow platinum blade. Wyeth uses a single needle. Both are attached to suitable holders by which they are grasped by the operator.

Complete anæsthesia of the patient is usually necessary, though in the case of small growths in suitable patients a local anæsthetic may be given.

An indifferent electrode—a large metal plate—is secured to some convenient part of the patient's trunk, and connected to one of the terminals of the machine. The active electrode is attached to the other terminal. The machine is set in operation and the point of the needle or blade brought into contact with the tissue at the spot at which the incision is to commence. Just before it makes contact the tiny arc appears at the point. Without delay the electrode is drawn across and into the tissue so as to make the incision. On each side of the advancing electrode the tissue falls away and shows a whitened appearance of the separated surfaces. The electrode must not be allowed to remain at rest in any one position for more than a moment. Otherwise the arc will carbonise the tissue in contact. If the divided surfaces are not carbonised the wound will heal by first intention. At the end of each incision the electrode should be withdrawn from the tissue.

At the moment when the active electrode touches the tissue and the arc is formed there is a twitch of the muscles in the vicinity. A similar twitch occurs at the moment when the electrode is lifted away from the tissue and contact broken. If the handle bearing the active electrode is fitted with an interrupter key the current can be stopped before the electrode leaves the tissue, and the twitch at break of contact avoided. The twitch at make cannot be avoided; if the current is not started *before* the active electrode makes contact with the tissue the arc will not be formed.

When the active electrode is drawn across vessels of appreciable size (say those which are macroscopic) the arc will not seal the divided ends, and bleeding will occur. They can be quickly sealed, however, in the following way. The

bleeding ends are seized by pressure forceps, the active electrode is placed in metallic contact with the latter and a strong diathermy current is now directed along the forceps. This current will coagulate the tissue at the tip of the forceps and seal the divided ends. The forceps is then removed.

When used for the purpose of sealing vessels in this way the current plays a different part; it does not produce an arc or divide tissue. It heats the severed end of the vessel and the tissue in immediate vicinity, and coagulates them *en masse*.

The current provided by Schall's portable machine plays both parts. It provides the arc for dividing the tissue, and when no arc is formed it can attain an amperage high enough to coagulate tissue *en masse*.

The cutting current provided by Wyeth's machine cannot coagulate tissue *en masse*. For this reason the machine is constructed with additional parts for the purpose of providing another current that can yield diathermy. By turning a switch this current can be taken to the same electrodes and used to seal vessels when they are divided.

This method of sealing vessels was described by Grant E. Ward.[1] A similar method is used by Anderson.

As already mentioned, healing follows by first intention after the surfaces, divided by the arc, are brought into contact and sutured. Soft narrow scars are left. If, when the tissue is divided at the operation, the machine has been adjusted to give a relatively small output, the whitening of the divided surfaces proceeds to a very slight depth (*e.g.* $\frac{1}{10}$ mm.). The ultimately formed scars are, then, very fine and narrow. Thin needle electrodes and small currents produce fine scars. Thick needles and large currents whiten the divided surfaces to a greater depth and provide a thicker protective covering, but thicker scars will eventually be left.

It might be thought that the inclusion of the coagulated tissue in the wound after suture, and particularly the imprisonment of coagulated tissue at the end of divided vessels, would cause shock after operation. The writer

[1] *Medical Journal and Record*, N.Y., April, 1925, CXXI. 470.

was personally assured by Dr. Wyeth that this was not the case.

A brief account of Anderson's experience in the radical amputation of the breast by the cutting current is given on p. 276.

In a recently published monograph Wyeth [1] has described his experience in the removal of new growths by means of the current from his specially constructed machine. Several cases are described, and illustrations are shown of the parts before and after operation. Malignant growths of the skin, and of the mucous membranes of the lips, tongue, floor of mouth, rectum and vulva were treated. Wyeth prefers to perform a preliminary circumvallation and coagulate the healthy tissue around the growth. The endotherm knife is then directed along and within the coagulated wall so as to divide it into an inner and outer layer. In this way the growth is excised and a cavity left with a coagulated wall.

If the growth has a low grade of malignancy, Wyeth omits the circumvallation, excises the neoplasm and closes the cavity by sutures. Healing by first intention can then be obtained. Healing by first intention cannot occur if circumvallation is performed.

Wyeth describes also the radical amputation of the breast and partial amputation of the tongue by the endotherm knife. He has also used the latter for laryngofissure in a case of intrinsic carcinoma affecting both vocal cords.

Wyeth's method has been warmly lauded by Howard Kelly, of Baltimore, who has practised it widely. The name "acusector" was devised by Kelly for the needle electrode employed by Wyeth. Kelly's opinion of the method can be learnt by reading a paper contributed by him to the *Medical Journal and Record*, New York (July, 1925, CXXII. 1). A quotation is given below:

"In the old-fashioned, bloody surgical operations, commonly in vogue, I now begin to think with some repulsion of the messiness of the procedure, the sponging, the tying, the needling, and the

[1] *Surgery of Neoplastic Diseases by Electrothermic Methods*, by George A. Wyeth. Paul B. Hoeber, Inc., New York.

general manipulations of the wound, which must contribute to so many bad results. I therefore welcome this new method of coagulation as a great addition to our technique, not only enabling us to do some things better, but greatly enlarging our field of beneficient activity. I give the Wyeth sector the leading place and decided preference in my daily work, relegating the scalpel to a subordinate position."

"These methods are not to be learnt completely in a week or a year. They call for careful attention to a new technique, for discriminating judgment in their application and for increasing boldness with a growing experience. The concept is a new one."

Anderson has had a lengthy experience of the use of the cutting current in surgery. He has employed it in over 80 cases of malignant disease of the breast. A brief account of his experience will be found later (p. 276), when the treatment of malignant disease in special regions is considered. He has also used the cutting current for the excision of non-malignant tumours and has obtained perfect healing. He has also used it for the removal of bladder tumours by the open method, and for the excision of malignant tissue for the purpose of diagnosis. At the time of writing he has not yet published his results, but has very kindly allowed the author to give a description of his work and methods for the purpose of the present book.

(7) Electro-desiccation

In this operation abnormal tissue is killed by heating it with a high-frequency current, but the degree of heat is insufficient to cause coagulation. The electrically produced heat deprives the tissue of water and dries it; hence the name "desiccation." The current used for this purpose is derived from an Oudin resonator attached to a diathermy machine. The resonator supplies a current at higher voltage than that provided by the diathermy machine, but the amperage and heating power are less. The active electrode consists of a single needle attached to an ebonite holder provided with a make-and-break switch. No indifferent electrode is used. A high potential is attained at the free end of the resonator, and if the needle electrode is attached and the point brought near a conductor, such as the body, sparks will pass between the latter and the tip

of the needle. The length and thickness of the sparks can be adjusted by varying the width of the spark-gap of the diathermy machine and the amount of current supplied to the latter. Widening the spark-gap lengthens the spark from the needle. Increasing the amount of current to the machine thickens the spark. If the sparks are thin they will not desiccate, while if they are too thick they will produce coagulation instead of desiccation.

The best way to learn the correct adjustment of the machine and study the process of desiccation is to experiment on a piece of soap.[1] The American types of diathermy machine are most suitable for the purpose, as they contain multiple spark-gaps which allow the widest and most delicate adjustment. One of these, that by H. G. Fischer, of Chicago, was described on p. 68.

The machine is adjusted so that it takes the minimum current, and all the spark-gaps, save one, are closed. The remaining gap is considerably narrowed. If the point of the needle is now brought almost in contact with the palm of the hand very short sparks will pass, and heat will be felt. Widening the gap makes the sparks longer but thinner. If now a little more current is supplied to the machine the sparks will become a little thicker.

The point of the needle is introduced for a short distance into the soap and the current allowed to pass for a few seconds. The part immediately around the needle will dry. By inserting the needle a little further the soap will be dried to a greater depth, but a little more current will be needed and the spark-gap must be made a little wider. By inserting the needle into closely adjacent regions and repeating the process a wider area of soap can be desiccated. The desiccated portion can be powdered.

The experiment can be repeated on raw meat. When the latter is desiccated it acquires a greyish colour. If the sparks are too thick, or if the needle is held for too long in one position, the meat will be heated to a temperature too high for desiccation, and coagulation will occur.

[1] The author is indebted to Dr. W. L. Clark for a demonstration of the method of electro-desiccation at the clinic of the latter at Philadelphia. This form of treatment was devised by Dr. Clark, who also introduced the name by which it is known.

A considerable amount of practice is required before the operation of electro-desiccation can be efficiently performed.

Therapeutic Field for Electro-desiccation.—This form of treatment is popular in the United States and many good results have been claimed. It is employed for growths, infective granulomata and other forms of abnormal tissue which do not extend deeply below the surface. The advantages which are claimed for the treatment are the very slight degree of inflammatory reaction after the operation, the small amount of scar tissue which replaces the destroyed part, the excellence of the cosmetic appearance and the permanence of the results. It is said that the extent of the destruction can be exactly localised, so that it is possible to treat corneal ulcers and papillomata of the vocal cords.

On account of these claims a lengthy trial should be given to electro-desiccation by workers in this country. By reason of the relatively low degree of heat employed in the treatment it can be understood that the local reaction should be mild and the cicatrisation reduced to a minimum. This low degree of heat, while just sufficient to deprive the cells of life, causes (it may be supposed) the minimum degree of decomposition of the tissue proteins. It can also be understood that the higher temperatures attained during *coagulation* produce a less mild reaction, although it must be admitted that it is less severe than that which follows treatment by red-hot metal, and that the resultant scar is softer after coagulation than after an actual burn.

As already stated, the reaction following fulguration is very mild. With this form of treatment it is not possible to destroy more than a slight depth below the surface without carbonising that which lies superficial to it.

Histological Appearance of Tissue treated by Various Electro-thermic Methods.

In order to ascertain the appearance a kidney, excised during post-mortem examination, was submitted in part to the operation of diathermic coagulation, in part to

fulguration, while a third portion was incised by the arc method. The kidney was then fixed in formalin, and the coagulated and fulgurated parts were cut through their centres, the plane of cutting being at right angles to the surface. The incised portion was cut at right angles to the plane in which it was divided by the arc. The sections were stained with hæmatoxylin and eosin. The writer is indebted to Dr. Canti for the following description of the microscopic appearances.

Tissue coagulated by Diathermy. "The area treated is depressed. The cells on the immediate surface are devoid of nuclei and flattened out, giving the appearance somewhat of the horny lay of the skin. The cells below this area show good nuclear staining, but they are shrunken and separated by empty spaces. It is suggested that these spaces were filled with steam which tore the tissue apart. The area below this appears normal, but it must be remembered that heat is a histological fixing agent, and that while excessive heat would destroy the tissues, moderate heat would produce fixation similar to that produced by formalin. It would not, therefore, be possible to discern the line where heat fixation ended, seeing that the whole tissue was subsequently fixed by formalin."

Fulgurated Tissue.—"Changes are very slight. The surface cells are not destroyed. The fulgurated area is best appreciated by a slight depression seen on examining with a hand lens." [1]

Tissue cut by the Arc Method.—"There is very much less destruction of the cells than that produced by diathermic coagulation. The sides of the incision show similar changes to those already described, but the layer of flattened cells is very thin and discontinuous, so that cells showing good nuclear staining are in many places to be seen at the surface. The 'boiled' appearance is only present here and there. As before, the limit of heat fixation cannot be determined."

Tissue subjected to Electro-desiccation.—Clark has studied the changes which the cells undergo during electro-desiccation. After they have been submitted to this treatment

[1] The tissue was fulgurated only to a slight depth and was not rendered brown or black by prolonged sparking.

they are shrunken, their nuclei are condensed and elongated and there is just a suggestion of cell outline. Clark likens the appearance to that of mummification.

Comparison of Electro-thermic Methods with the actual Cautery and the Scalpel.

It has already been shown that tissue is destroyed only for a very short distance below and around red-hot metal. If tissue at a greater depth is to be destroyed the superficial portion must first be burnt away. In the process of moving the hot metal through the tissue the blood vessels are destroyed and bleeding occurs from those which are of appreciable size. The diathermy current, on the other hand, can coagulate a relatively considerable mass of tissue without disturbing its anatomical continuity or that of the blood vessels or lymphatics. Although the vessel walls are coagulated no bleeding occurs, even from large vessels. If the blood is not immediately coagulated *by the heat* it coagulates later by the normal process of *thrombosis*.

The tissue proteins undergo a more profound and complete chemical change when red-hot metal is used than when they are coagulated by the diathermy current. By reason of the intense heat they are decomposed and, in part, converted into carbon. When the diathermy current is used the temperatures attained are much less high (not higher than that of the boiling-point of the tissue fluids) and the protoplasm is converted into coagulated protein. It is unlikely that the latter is further decomposed into non-protein bodies. When the diathermy current is used to desiccate tissue the temperature attained is still less high: the protoplasm is dried, not coagulated, and there is still some evidence of cell structure.

The local and general reactions which follow the use of the electro-thermic methods are much less than those which occur after the use of the actual cautery or the knife. After burning with hot metal shock is likely to occur. After coagulation, even of relatively large masses of tissue, shock does not occur. After cutting operations by the arc method the patients are said to suffer less shock than after similar

operations performed with the scalpel. As stated on p. 277, Anderson found that patients who had undergone operation for removal of the breast were in good condition after leaving the operating table. After burning with hot metal the local reaction may be severe, and hard adherent scars are likely to form. After coagulation by diathermy the local reaction is slight and the scars which replace the destroyed tissue are soft, pliable and non-adherent. After electro-desiccation it is said that the local reaction is scarcely apparent and that the best scars are left.

Part III

ELECTRO-THERMIC METHODS IN THE TREATMENT OF MALIGNANT DISEASE

In this part the subject is considered in general. The advantages and limitations of diathermy, and the factors which decide the suitability of cases and the selection of the method of application, are shown. The procedure when the growth is easily accessible, first, when it is ineradicable, second, when it is eradicable, is described. The results of diathermic coagulation on the tissues and on the patient are shown. A note is added on the present-day position of diathermy in the surgery of malignant disease.

Of the different electro-thermic methods for the treatment of malignant disease, those which produce *coagulation* of the growth or of a wall of healthy tissue around it have been most widely employed. In the following pages these methods will be described and the experience gained from their use will be related. The use of the word "diathermy" or the expression "diathermic coagulation" is intended to refer to the operation in which the diathermy current is employed for the purposes mentioned above. The excision of malignant tissue by the arc electrode has been practised, so far, by only a few workers.

Advantages attending Use of Diathermy Current.—If the current is employed to coagulate malignant tissue, not only is the growth destroyed but the smaller blood vessels and lymphatics are sealed. Infecting organisms are also destroyed. The patient suffers little, if any, shock, and his

stay in bed is very short, even if a large mass of tissue has been coagulated. Pain, if present, is almost always relieved. Complications are rare.

If the current is employed to coagulate healthy tissue around a malignant mass, the latter can be removed without risk of dissemination and another advantage, in addition to those enumerated above, is gained.

Limitations of Diathermy.—The diathermy current coagulates healthy as well as unhealthy tissue, and, if both are present in the part subjected to the heat, both will be destroyed. It is not always possible to limit the range of action of the current. It is evident, therefore, that complete destruction or removal of growths is not possible in some cases and in some situations.

Factors determining suitability for Treatment by Diathermy.—If a growth is to be treated by diathermy it must be *accessible*—that is to say, within reach of the active electrode, because the latter must be placed in contact with it. Growths of the skin, and of the mucous membrane of the mouth, nose, tongue, pharynx, larynx, œsophagus, rectum, bladder and cervix uteri can be treated. Growths which arise from the wall of the stomach and intestine and project into the lumen might be treated—after exposure by surgery—if the destroyed tissue could slough into the lumen and so make its way to the exterior, measures being taken to render its escape elsewhere anatomically impossible.

If the growth has infiltrated into parts which cannot be destroyed without risk, no hope can be entertained of complete removal. Diathermy is no respecter of tissues.[1] Normal tissue and new growths are destroyed alike if they lie on the path of a current of sufficient intensity to coagulate the latter. Widespread neoplasms are, however, in many cases, suitable for *palliative* treatment by diathermy, and the benefit, though temporary, may be considerable.

Growths which are less widespread but too extensive for the scalpel are, in many cases, suitable for diathermy.

[1] Although the lethal temperature for malignant tissue is slightly lower than that for normal tissue, no method has yet been devised whereby diathermy might be applied so as to heat infiltrated tissue throughout to the lower temperature. The task would be one of great difficulty.

Cases of this kind formed the bulk of those which were treated during the first decade of the use of surgical diathermy at St. Bartholomew's Hospital. The results were so encouraging that the treatment was tried for earlier cases. At the present day surgeons have adopted diathermy for the treatment of malignant disease of the mouth and throat, and some prefer it to the knife even in cases which, hitherto, they would have treated by excision.

If the general condition of the patient is bad, and cachexia is present, treatment by diathermy is inadvisable. If performed on such cases, pain will probably follow, and, if present, it may be aggravated. There is also a risk of hæmorrhage after the operation. The presence of glands enlarged by the growth is not a contra-indication against diathermy if cachexia is absent. They may be excised before or after the diathermy, at a separate operation.

Choice of Operation.—This will depend on various factors. If the growth is *eradicable*, that is, if it is surrounded by a fair margin of healthy tissue that can be cut or coagulated without detriment to the patient, the operation of circumvallation should first be performed. After the formation of the isolating barrier the enclosed tissue should then be removed. The removal can be effected by the combined coagulation and cutting operation, but the same object can be achieved with greater dexterity, neatness and safety by the operation of cutting with the arc. If healthy tissue can be cut at a considerable distance from the growth, the operation of circumvallation may be eliminated and the "arc-electrode" used in place of the scalpel. The cut surfaces can then be brought together, and healing by first intention will occur. Operations of this kind are now under trial.

If the growth is *ineradicable*, the operation of diathermic coagulation should be performed and as much of the growth destroyed as possible.

The choice of operation will depend also on the degree of *accessibility* of the growth. If the growth is situated on the exterior of the body, or in the mouth or certain parts of the oro-pharynx, the active electrode can be freely moved and manipulated: the growth will then be described as

"easily accessible." If, at the same time, it is eradicable the operation of choice is circumvallation followed by excision. If it is ineradicable the only operation that can be performed is diathermic coagulation of as much of the growth as is possible.

If the growth is situated within the œsophagus, bladder or rectum, the active electrode can be brought into contact with it but it cannot be freely manipulated. The growth will then be described as "less accessible." The only operation that can be performed is diathermic coagulation; circumvallation and excision cannot be practised.

Growths within the bladder or rectum can, however, be rendered easily accessible by exposing them by means of the scalpel. In the same way growths within the antrum and other sinuses of the nose and the nasopharynx can be exposed and treated by diathermy.

Anæsthetic.—If diathermy is to be applied to small portions of tissue, in less sensitive regions, that can be destroyed in a few seconds, and with weak currents, no anæsthetic is required. If a large mass is to be destroyed the heat will accumulate, especially if stronger currents are used and for longer periods, and the tissues will become unbearably hot, so that an anæsthetic is necessary. A general anæsthetic is necessary if the patient cannot be trusted to remain still, especially if the treatment is to be applied to less accessible parts, such as the larynx and nasopharynx. For most of the cases that have been treated at St. Bartholomew's Hospital, a large proportion of which were ineradicable malignant growths, a general anæsthetic has been used.

Ether should never be used when surgical diathermy is performed in the mouth, throat or air passages. Sparks would certainly explode ether vapour and air when mixed in the right proportions. It is not safe to use ether even if the site of the operation is the other end of the body. If ether vapour is in the atmosphere of the theatre the latter might be wrecked by explosion.

The Indifferent Electrode and its Position.—The indifferent electrode should be placed on the trunk, either chest or abdomen, when the patient is lying on his back. To ensure

even contact with the skin a folded towel, measuring, when, folded, say 8 inches by 10 inches, well soaked in hot saline, is interposed between the metal and the skin. The metal plate may measure about 6 inches by 8 inches. It should be bandaged in position. It is a matter of great importance that the moistened towel should make contact at all points with the body, and that it should not get dry, otherwise the skin will be burnt, particularly if long applications are made. It is very necessary that strong solution, not less than 10 per cent., should be used for saturating the towel. If weak solution or tap water are used they will present a high resistance to the current, their temperature will rise, and the skin may be scalded.

The indifferent electrode need not be applied if the patient rests on a condenser couch.

Preliminary Ligation of Arteries.—If the growth has spread to the vicinity of an artery of appreciable size it is advisable to ligate the vessel or the trunk from which it arises before commencing the diathermy. In cancer of the tongue it is wise to tie the lingual artery unless the growth is small and superficial. In the case of widespread growths in the oral and pharyngeal regions it may be necessary to ligature the external carotid artery.

Ligation of arteries prior to diathermy is advisable in order to prevent the so-called "secondary hæmorrhage" which may occur if the walls of the vessels are damaged during the treatment.

A. Malignant Growths in easily accessible Situations.

(1) *Ineradicable*

If a malignant growth is ineradicable, diathermy should be applied with the object of coagulating as much of it as possible. Fungating masses should in addition be excised, but it is inadvisable to attempt to excise the infiltrating portions. If the growth is readily accessible it can be destroyed more completely (or less incompletely) than when it is in more remote regions and free manipulation of the active electrode is impossible.

Active Electrode.—A disc electrode should first be used. Its diameter should be equal to the depth to which it is desired to destroy tissue. If, however, the depth exceeds 10 or 15 millimetres it is undesirable to use discs of larger diameter, because the process of coagulation will be slowed and tissue may be destroyed to a greater depth than the diameter of the electrode. They may be used, however, for fungating growths in order to destroy the exuberant mass. If the largest discs are used the current may not attain sufficient density or heating power to destroy more than the superficial parts of the growth.

If the depth of infiltration exceeds 10 or 15 millimetres the single-needle electrode should be used, inserted to the desired depth and the tissue around it destroyed. The process should be repeated in closely adjacent regions until all the tissue is destroyed. Multiple-needle electrodes should not be used, for the same reason as that which renders undesirable the use of large discs. They may be used for the destruction of fungating masses.

In cases in which the depth of infiltration is greater than 10 or 15 mm. the disc electrode of this width may, with advantage, be used first. The destruction to a greater depth may then be continued with the single-needle electrode.

Regulation of the Diathermy Current.—Before the diathermy current is switched on, the electrodes must always be in position. The disc is placed in the desired position, and it must not be moved from the body until the current is switched off; otherwise torrents of sparks will dart between the electrode and the body and perhaps burn neighbouring parts; while anyone who touches the indifferent electrode, or the uncovered skin of the patient, or the uncovered end of the active electrode, may receive sparks.

The diathermy current should be started from zero, and its strength should be gradually increased. The regulating handle which controls the strength of the current should be moved from zero towards maximum, and about ten seconds should be occupied in the movement. Just before sparks appear, current should be stopped, and the regulating handle moved to zero. The disc is then placed on an adjoining region, and the current again started and

increased as before. The process is repeated till all the tissue which is to be destroyed has been coagulated.

The changes which take place around and under the disc, and the sounds due to the escape of steam and passage of sparks, have already been described. The operator can soon learn, after a little practice on excised tissue, the correct time for stopping the current. The passage of sparks between the edges of the disc and the uncoagulated tissue is not harmful, although muscles in the vicinity may contract. The passage of sparks is an indication that the tissue immediately under the disc has dried. Dried tissue may adhere to the electrode.

When the single-needle electrode is used and inserted in position the current should be increased gradually, as before. It should be stopped at the moment when coagulation is visible on the surface around the shaft of the needle. As mentioned before, the coagulation begins at *the point* of the needle and spreads up the shaft.

If the tissue in contact with the electrode becomes quite dry it will adhere to it. Sometimes it adheres so tenaciously that a portion of the coagulated tissue comes away with the electrode when the latter is removed. A sharp instrument may then be necessary to remove the adherent tissue. If even a thin layer of dried tissue remains on the electrode when the latter is re-applied, sparks will quickly appear when the current is started and the tissue will not coagulate to the proper depth.

It is tempting, after coagulating the malignant tissue, to scrape it away with a Volkman's spoon or blunt instrument. This is not to be recommended, because bleeding is almost certain to occur. In the lowermost region to which the coagulation has extended, only the fixed tissues will be coagulated, not the circulating blood, and the latter will escape if the coagulated tissue is scraped away.

Bleeding may occur after removal of the active electrode if dried tissue adheres to the latter, especially if the growth is friable. Uncoagulated tissue may adhere to the dried portion and come away with it when the electrode is moved.

Bleeding may also occur as a consequence of the heating of the malignant tissue in the neighbourhood of the active

electrode. The parts around the electrode soon become very hot and blood begins to ooze away from regions from which it did not escape before diathermy was applied.

If bleeding takes place, the region from which it occurs should be covered by the disc electrode and the latter pressed against the part so as to block the escape. The current should then be started and gradually increased until steam escapes. If a few drops of strong hot salt solution are placed around the electrode the latter can be removed without bringing tissue with it and starting the bleeding afresh. If blood escapes from an area too large to be covered with the disc, the bleeding from the uncovered area should be stopped by pressure with a small swab while the tissue in contact with the disc is being coagulated. The disc can then be placed on an adjoining area and the process repeated until the bleeding is permanently stopped. If blood escapes during the process of coagulation the hæmoglobin is decomposed by the heat and the field of the operation is obscured by a dark tar-like covering.

(2) *Eradicable Growths*

If a malignant growth is movable and there is a fair margin of healthy tissue around it, the diathermy current may be employed for its removal, provided it is readily accessible.

A preliminary circumvallation should always be performed. The single-needle electrode should be used. The procedure has been described (p. 232). After the isolating barrier has been formed a portion of the growth may be taken for examination. The growth itself can then be removed by means of the blade electrode. The combined coagulating and cutting operation may be adopted. This has been described on p. 233.

The blade electrode is introduced into the tissue just within the isolating wall of coagulated tissue. The current is increased until the tissue around it is coagulated. It is then moved forwards in the direction of its cutting edge, allowing time for the tissue to coagulate in advance, until the part within the wall has been separated.

The excision is not easy to perform with neatness. The operator has to use some effort in moving the blade forward, unless an up-and-down movement is made at the same time; this may result in the division of the coagulated wall, especially in the region of the point of the blade. If the blade is unduly delayed in any region the coagulated tissue around it will dry and sparks will appear.

The tissue can be excised with much greater ease and neatness by the arc-operation. For a description of this method see p. 239 *et seq.* It has already been mentioned that the Schall portable model provides a current which is most suitable for cutting and can also procure diathermic coagulation. This machine possesses the draw-back that it requires attention while it is working.

Machines must be specially designed and contain three-electrode thermionic valves if they are to yield the best cutting-current uninterruptedly and without attention.[1] This current may not be able to produce diathermic coagulation; it is then necessary to fit additional parts so that a diathermy current can be obtained when desired.

B. Malignant Growths in less accessible Regions.

The application of diathermy to growths in regions such as the postcricoid region of the pharynx, œsophagus, bladder and rectum requires the use of special electrodes and handles as well as accessory apparatus. The subject will be considered later when the treatment of malignant disease in special regions is described.

Results of Diathermic Coagulation of Tissue.

(1) *Local.*—The tissue in the region of the coagulation quickly becomes œdematous. The œdema begins during the operation. It is most apparent when diathermy is applied to growths of mucous membranes. It persists after the heated tissue has regained its normal temperature, and

[1] A machine is now being designed for this purpose by A. E. Dean & Co.

may not subside until one or two days have passed. Exudation of lymph begins soon after the appearance of the œdema. It persists while the œdema lasts and may be profuse for twenty-four hours and cause thirst.

Œdema may appear in the eyelids after coagulation of growths or ulcers of the face near the eyes. Swelling of the lids is apparent a few hours after the operation and may attain a degree sufficient to prevent the patient from opening his eye. The œdema subsides gradually and the lids regain their normal condition in a day or two. Œdema of the eyelids may occur after diathermic coagulation of growths or ulcers of the face at some distance from the eye, *e.g.* on the lower part of the cheek.

Considerable swelling of the neck occurred in a case in which the author coagulated enlarged tonsils without excising the destroyed tissue.

The coagulated tissue begins to separate after two or three days. The separation of the slough is complete in two to three weeks.

Granulation tissue quickly fills the cavity left by the slough, and new epithelium covers it. The new tissue does not shrink or form adhesions with parts which may be in contact.

Keloid sometimes develops in the skin. This is more likely if the coagulation has been restricted to the skin. It has been seen in cases in which the skin was accidentally coagulated under the indifferent electrode: also in some cases of lupus which were treated by diathermy.

(2) *General.—Effects on patient.* Shock rarely occurs after coagulation of tissue by diathermy, even if a considerable mass has been destroyed. In all the cases in which the writer has made inquiry, signs of shock, such as fall of temperature, cold extremities, feeble pulse, etc., were not observed after the operation. The patients, after return from the operating theatre, are packed in blankets with hot-water bottles, and the signs mentioned do not occur. A rise of temperature is sometimes noted on the day after the operation, but, unless complications occur, it subsides on the third day. It usually reaches 99·4° or 100°, rarely a higher value.

Pain is slight or absent, and if present before the operation, is usually relieved. The degree of discomfort following the greater number of cases of operation by diathermy is surprisingly small, if the general condition of the patient is fairly good before the coagulation and cachexia is not present. The patient is able to sit up in bed on the day after the operation and get up on the third day. The separation of the slough is a source of discomfort more to the attendants of the case and the other inmates of the ward than to the patient himself, as the odour is disagreeable and penetrating. After the separation is complete the odour disappears.

If the general condition is bad before the operation and cachexia is present, the patient suffers much after the operation and pain is increased. As noted above, it is inadvisable to perform diathermy on such cases.

Complications.—The complications which may arise after diathermic coagulation are few, and most of them can be prevented.

The œdema which develops during and after the coagulation may cause obstruction of the glottis when growths in the vicinity of the larynx are subjected to diathermy. The risk of asphyxia can be averted by tracheotomy. This operation should be performed before the application of diathermy, because the obstruction may occur later, when the surgeon is away.

Œdema is likely to obstruct the lumen of the pharynx or œsophagus when diathermy is applied to growths which are situated in these passages and narrow the channels. The electrode maintains their patency during the operation, but tubes should be passed and kept in position as soon as the diathermic coagulation is complete.

If an artery of appreciable size, *e.g.* the lingual, lies in close vicinity to a growth which has been coagulated by diathermy there is always the likelihood of hæmorrhage if the vessel or its parent trunk has not been ligated previously. The hæmorrhage occurs when the separation of the slough is well advanced, that is, in about a week to ten days after the operation.

The lingual artery was the commonest source of this

so-called "secondary" hæmorrhage before the custom of ligating vessels prior to diathermic coagulation was adopted. Secondary hæmorrhage has also occurred from the temporal and ascending pharyngeal arteries as well as from smaller vessels.

If the general condition of the patient is bad and cachexia is present there is a likelihood of hæmorrhage at an earlier date.

Septic infection of the slough, or of the underlying tissue after the slough has separated, is a very rare occurrence. Suppuration in the glands receiving lymph from the coagulated region occurred in two of the cases treated at St. Bartholomew's Hospital. In one of these septic thrombosis occurred.

Septic broncho-pneumonia is an occasional complication after diathermic coagulation of growths of the mouth, pharynx and larynx, but it occurs less commonly than after cutting operations with the scalpel.

Sudden death has never occurred, as far as the author is aware, *during* coagulation by diathermy. During convalescence it occurred in one case without apparent cause, and as autopsy was not allowed, the reason was not ascertained. This was a private case of carcinoma of the tongue. The anterior portion of the organ was excised by the blade electrode. The operation was lengthy and over an hour was occupied in its performance.

In another case death occurred about four hours after completion of the operation. The patient, a man aged 66, had a carcinoma invading part of his tongue, faucial pillars, floor of mouth, and soft palate. No enlarged glands were felt, there were no signs of secondary growth, and the general condition of the patient was good. No shock followed the operation. The patient had not fully regained consciousness after the anæsthesia. No autopsy was allowed in this case.

After-care.—Until the slough has separated and healing is complete the wound requires simple surgical dressing if on the exterior of the body. If on the mucous membrane of the mouth or throat, frequent irrigation with antiseptic and deodorising solutions, such as hydrogen peroxide or listerine, is advisable.

It is of the utmost importance that the patient should report at regular intervals so that the site of the treatment can be examined. If recrudescence occurs diathermy should be repeated.

Position achieved by Diathermy in the Treatment of Malignant Disease.—Diathermy has passed the stage of competitive trial and its value is now established. During the first decade of its use in *ineradicable* malignant disease its power was realised. During the succeeding five years it was extensively used in *eradicable* cases, and at the present day it is employed by many workers for the treatment of malignant growths which, in earlier days, would have been excised by the scalpel.

It is in the treatment of malignant disease in the upper air passages that the widest experience has been gained. In the *Acta Oto-Laryngologica* (Vol. VII. fasc. 4) a number of articles were written by various workers on surgical diathermy. In one of these articles W. D. Harmer concluded "that in early cases diathermy gives far better results than simple cutting operations." Norman Patterson wrote that the "results obtained by diathermy in early as well as in advanced cases are much better than those which follow treatment with the knife." Dan McKenzie wrote: "Turning now to cancer, and in the first instance to *cancer of the pharynx*, we can, I think, express the opinion that no remedy hitherto available can equal diathermy in the treatment of cancer of the throat."

At a discussion on surgical diathermy held at the house of the Royal Society of Medicine on December 17th, 1926,[1] the following opinions were expressed.

F. J. Steward said that if a comparison were made between diathermy and the ordinary cutting operations the superiority of the former would be evident, provided cases were carefully chosen and certain conditions of technique were observed.

Mr. Gwynne Williams remarked that he had not used a knife for the past six years in the treatment of carcinoma of the tongue and the floor of the mouth.

H. H. Rayner said that he was convinced of the value

[1] *Proc. Roy. Soc. Med.*

of diathermy for surgical purposes in the treatment of malignant disease generally, whether applied to oral or skin cases.

G. Gordon-Taylor, speaking of upwards of a hundred cases of operable carcinoma of the mouth treated by diathermy, said that he felt convinced that the ultimate results in cases treated by diathermy were better than those treated with scissors or the knife.

It is scarcely necessary, in view of the experience gained by the surgeons above named, to say that diathermy can achieve results which the scalpel cannot obtain in malignant disease. It has its limitations, as already described, and in some cases better results will be gained by radium or X-rays. The best " balance sheet " will be presented by the worker who knows the advantages and limitations of each agent and prescribes without prejudice.

The following case is a striking example of the success of diathermy after failure of ordinary surgical methods. The patient had an endothelioma which involved the nasal bone and inner wall of the orbit. The growth was freely excised by the scalpel together with the periosteum, the incisions being made well beyond the margin of the disease in every direction. The growth *reappeared within three months* and rapidly increased in size. It was then coagulated by diathermy. The treatment included the bone in the floor of the wound. The sequestrum separated after three months. The wound then healed rapidly. The patient remained well *for twelve years*, when two small nodules reappeared in the scar. This case was under the care of Douglas Harmer.

Part IV

DIATHERMY IN MALIGNANT DISEASE IN SPECIAL REGIONS

In this part are described the treatment of eradicable and ineradicable malignant growths in special regions, and the experience of various workers. These regions include the upper air passages, œsophagus, breast, female genitalia and skin.

1. Upper Air Passages.

If malignant disease is present in the mouth or throat, carious teeth should be removed and strict attention paid to the oral toilet for a week or two before the operation. If enlarged glands are present in the neck they should be removed if they are thought to be malignant. There is no complete uniformity of opinion regarding the date of this operation, whether before or after the diathermy. Most surgeons prefer to remove the glands a week or ten days before the diathermy. This also affords the opportunity of ligating the lingual, facial or external carotid arteries.

The coagulation of the glands by means of the single-needle electrode, each gland being repeatedly punctured, before their removal, is recommended by Dan McKenzie. He also advises the insertion of the needle electrode into the tissues deep to the angle of the jaw with the object of coagulating the cancer cylinders in the lymphatics between growths in the pharynx and the glands in the neck. The needle should not be inserted too far for fear of making a communication between the pharynx and neck.

The treatment of the primary growth and the selection of the operation are determined by the extent of the growth and its position. This has already been considered.

As soon as possible after the operation the mouth should be irrigated with hydrogen peroxide (10 per cent.) or solution of sodium hypochlorite (1 in 10). Later the patient can gargle his mouth and throat.

For the application of diathermy to the larynx and postcricoid region of the pharynx special electrodes and handles are used. An account of these and the experience gained by their use will be given below, after describing

the results obtained in the treatment of growths of the oral, nasal and pharyngeal regions.

Results obtained in the treatment of Malignant Growths in the Oral, Nasal and Pharyngeal Regions.—In this country the longest experience is that of Douglas Harmer. He concludes that diathermy is the best and surest method of destroying rapidly malignant ulcers of the mucous membranes of the upper air passages. In early cases it gives far better results than simple cutting operations. By its means he has been able to treat many cases that were inoperable by ordinary surgery, and to relieve them for long periods.

For cancer in the floor of the mouth Harmer is of the opinion that there is no treatment that compares with diathermy and that a cure can be expected in early cases. One of his patients presented a large ulcer in the mouth, adherent to the lower jaw. It was coagulated by diathermy. Eight years later the case showed no recurrence, and the glands in the neck did not enlarge.

In cancer of the tongue Harmer has obtained better results by diathermy than by simple excision by the scalpel. He coagulates the growth as completely as possible and then excises the coagulated tissue, leaving the widest possible margin between the latter and the line of excision.

A case of cancer of the tongue which was treated by the author for Sir D'Arcy Power remained free from local recrudescence until death occurred one year and eleven months later.

Harmer has treated many cases of advanced carcinoma of the tonsil involving the palate, tongue, pharynx and often the upper and lower jaws as well. A few cases were free from recrudescence for three years. For advanced malignant disease in this region he prefers to combine diathermy with X-rays.

In malignant ulcers of the hard palate diathermy has given excellent results. By thorough coagulation of the soft tissue and the whole thickness of the bone under the growth Harmer has obtained lasting cures.

In the treatment of growths of the upper jaw and nasal fossæ Harmer has obtained much better results from

diathermy than from excision by the scalpel. The growths were approached through the mouth or cheek, and in some of the cases the cavity was packed with gauze containing radium in order to destroy any malignant cells which might have remained after the diathermic coagulation.

Larynx and Post-cricoid Region of Pharynx.—Before the application of diathermy to growths involving the upper laryngeal orifice, the epiglottis, the ary-epiglottic folds, the sinus pyriformis or post-cricoid region of the pharynx it is advisable to perform tracheotomy in order to avert the risk of asphyxia from œdema of the glottis.

The growths may be brought into view by suspension laryngoscopy. As the active electrode a single needle or small disc or ball may be used. For growths obstructing the post-cricoid region of the pharynx a special electrode shown in section in Fig. 63 has been used.

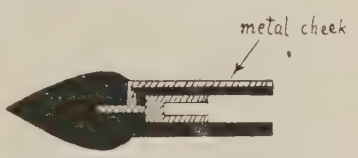


Fig. 63.—Electrode for post-cricoid carcinoma.

This electrode consists of a short ebonite rod terminating in a conical head. The rod bears, on part of its surface, a metal cheek of the same length as the rod. In breadth the cheek is one-quarter of the circumference of the rod. This electrode can be made in various sizes to suit the length of the stricture and the width of the narrowed lumen.

As made hitherto this electrode has, probably, too large an area of metal for contact with tissue. It is probable that Teall's electrode used for treatment of malignant stricture of the œsophagus (p. 272) would be better. In place of the special electrode a single needle or blunt rod has been used.

The electrode is attached to the free end of the handle shown in Fig. 64, and, in section, in Fig. 65. The part AB is grasped by the operator. It is made of ebonite. Deeply buried in it is a metal conducting core. To one end (A) is screwed the cable from the diathermy machine. Over the other end (B) slides the proximal end (C) of the middle-piece (CDE). This piece is made of insulated steel wire,

$\frac{3}{16}$ inch in diameter (over all), screwed into the ebonite end (CD), which slides over the projecting end (B) of the metal core of the handle (AB). The middle-piece is of the smallest possible diameter, so as not to obscure the view when passed along the air passages. The electrode is screwed on the end E.

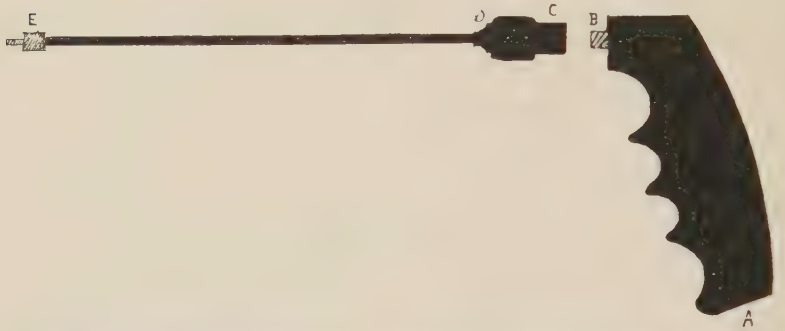


Fig. 64.—Handle for attachment of electrodes shown in Figs. 63 and 66.

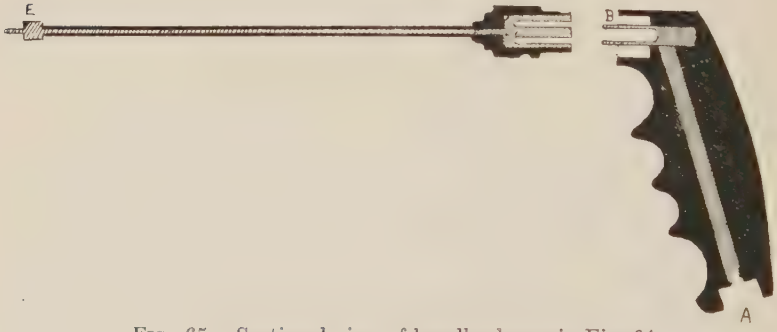


Fig. 65.—Sectional view of handle shown in Fig. 64.

When the active electrode and the parts of the handle are in position, and the cable from the diathermy machine is attached to the end A of the handle, there is no bare metal except at the free end which makes contact with the tissue. Everywhere else the metal conducting core is covered with insulating material.

After the coagulation of growths obstructing the hypopharynx a tube should be passed through the stricture

and maintained in position for three days in order to allow the passage of food during the period of œdema and swelling.

Harmer has applied diathermy to a number of cases of post-cricoid carcinoma, but has since abandoned this form of treatment in favour of other methods. In two cases, however, the obstruction to swallowing was relieved for a few months and the general condition of the patient was considerably improved. Another case derived no relief and the fourth case was benefited a slight degree. Two other cases died on the fifth and eighth days after the diathermy, one from hæmorrhage and the other from broncho-pneumonia.

Dan McKenzie has applied diathermy to several cases of post-cricoid carcinoma by means of a blunt terminal attached to a long handle. The effect on swallowing was good. He found it difficult to estimate the depth of coagulation; in two cases abscesses formed at the root of the neck and formed long tortuous fistulæ.

The application of diathermy to the growths behind the cricoid is attended by the risk of perichondritis.

Diathermy has given some good results in carcinoma of the epiglottis, but for the treatment of growths in the region of the upper laryngeal orifice elsewhere it has not, so far, been satisfactory. Trial should, however, be given to the method of cutting by the arc. By this method it is possible that the risk of perichondritis might be averted.

Nasopharynx. A case of angio-sarcoma of the naso-pharynx was treated by Broughton Barnes. He removed the growth by means of his snare electrode. There was no loss of blood and the patient was free from recurrence two years later. The electrode is described on p. 290 and illustrated in Fig. 54 (p. 291). The particulars of the case are given below.

The patient was a boy of 13. The tumour arose from the basi-sphenoid. It was 1 in. long, and its pedicle was $\frac{1}{2}$ in. broad and $\frac{1}{4}$ in. thick. The body of the tumour was 1 in. in breadth and $\frac{3}{4}$ in. in thickness. Its free end was visible below the soft palate. The boy had had two severe attacks of hæmorrhage before he was brought for treatment. Under general chloroform anæsthesia the snare was passed through the mouth over the tumour and forced against the basi-sphenoid by the finger. The snare was tightened and the current started. The tumour fell free in about five seconds. There was no stain of blood. The patient had absolutely no discomfort

after the operation. Two years later there was no sign of recurrence, nor has there been any hæmorrhage since the operation. The histological appearance of the growth was that of an angio-fibro-sarcoma with enormous numbers of large thin-walled vessels extending even into the epithelium.

Mr. Broughton Barnes, who kindly furnished the writer with the particulars of the case, stated that the only precaution necessary was to maintain the pharynx in a low position when the tumour fell.

2. Œsophagus.

For the coagulation of growths of the œsophagus special electrodes have been devised by C. G. Teall, of Birmingham, and A. J. Wright, of Bristol. Teall's electrodes are

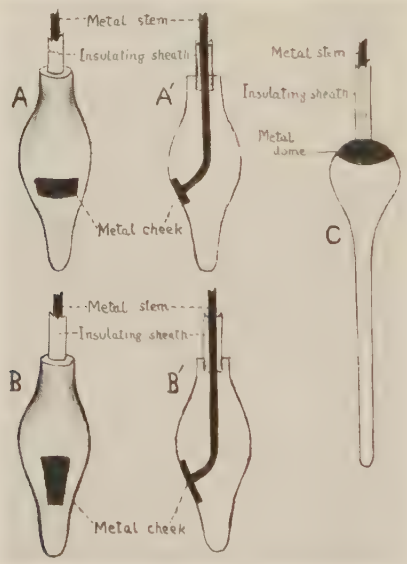


Fig. 66.—Teall's electrodes for treatment of malignant strictures of œsophagus. A and B are shown in section at A′ and B′.

shown in Fig. 66, A, B, C. They are made of ebonite. A and B contain small rectangular metal cheeks, their long axes being transverse in A and longitudinal in B. These electrodes are attached to insulated metal stems of suitable length. The other ends of the stems are secured to handles for the operator.

The stricture is brought into view by means of an œso-

phagoscope and the free end of the electrode is engaged in its proximal end. When the metal cheek makes contact with the latter the current is started and the electrode is moved slowly downwards and the growth coagulated along a path from above downwards. The electrode can then be slightly rotated and slowly withdrawn. In this way another path can be coagulated by the side of the first.

The depth to which coagulation can be produced with currents of different strength and with different rates of movement can be approximately ascertained by making preliminary experiments on raw meat. The small size of the metal cheek prevents coagulation to too great a depth. and the blunt rounded end of the electrode is a safeguard against making a false passage.

The electrode shown in Fig. 66, C, is also made of ebonite. At its proximal end is a metal dome. When this electrode is used it is passed through the stricture before the current is started. The metal dome is then brought into apposition with the distal end of the stricture and the current started. It is then slowly withdrawn along the stricture. The latter is coagulated along its entire surface.

This electrode is a modification of a similar instrument devised by Wright. In place of the dome Wright's electrode is fitted with a metal ring with a free cutting edge. It is passed through the stricture to the distal end; the current is started and the electrode withdrawn. The cutting edge then comes into contact with the growth, coagulating and cutting it at the same time.

There would seem to be more risk of bleeding when Wright's electrode is used. With Teall's electrode there is coagulation without cutting.

An œsophageal tube must be placed in position after the coagulation is complete in order to prevent the complete obstruction of the lumen which the swelling and œdema of the tissue would cause. It may be removed after three days.

Complete destruction of œsophageal growths by diathermy cannot be effected by the methods at present available. Attempts to destroy them in their entirety might create a passage into the mediastinum.

Considerable experience in the treatment of œsophageal carcinoma has been obtained by Musgrave Woodman. In a discussion on the treatment of malignant disease of the upper air and food passages he stated that he had had sixty cases with œsophageal disease. He had not been able to cure any of them, nor was he sure that he had been able to prolong life to any appreciable extent. In nearly all instances, however, he had enabled the patients to eat ordinary food *per vias naturales* until death occurred from extension of the disease. The results were superior to those obtained by gastrostomy. The patients were able throughout the disease to swallow freely by the ordinary route. The operation was well borne and produced very little shock.

3. Breast.

(*a*) *Ineradicable Cases*

Cases of advanced carcinoma mammæ in which the breast is extensively infiltrated and presents ulcers or fungating masses of growth are suitable for diathermy if cachexia is not present. Not many cases of this kind have been treated by diathermy. The author has had experience of five: in two the results were striking. The following is a *résumé* of the particulars of the cases, the treatment and the subsequent history.

Case 1.—The patient, a lady of 45, came under the author's care in November, 1921, suffering from Paget's disease of the nipple. She was thin and fragile and the subject of advanced but quiescent rheumatoid arthritis. In addition to the eczema of the nipple there were large movable masses in the breast. The eczema disappeared under X-ray treatment. The patient refused surgical treatment and would not consent to receive a general anæsthetic. The swellings in the breast gradually enlarged and became adherent to the skin. The latter ulcerated and fungating masses of growth appeared. Resisting X-ray treatment they increased in size, and there developed a large fungating mass measuring 7 inches by 4 inches and projecting 1½ inches from the surface.

Coagulation by diathermy was then commenced. The growth was destroyed, piece by piece, at successive operations, until it projected no more than about ½ inch from the surface. Up to this period the patient did not feel undue heat during the coagulation. A disc-electrode measuring 5 mm. in diameter was used. To enable the continuation of the coagulation a local anæsthetic was given, and the remainder of the growth was treated together with the skin at

the edges. In June, 1925, the greater portion of the chest wall formerly occupied by the growth was covered by scar tissue. Two slightly elevated masses remained: these measured, respectively, $1\frac{3}{4}$ inches by $1\frac{3}{4}$ inches and $\frac{1}{2}$ inch by $\frac{1}{2}$ inch. These were covered by a dusky epithelium. Since the date last stated the patient attended irregularly and infrequently by reason of changes of residence to localities at a distance from London. As a result, the growth increased in size and, at the time of writing (February, 1927) measures 3 inches by $2\frac{3}{4}$ inches. Its maximum elevation is about $\frac{1}{2}$ inch from the surface. Apart from occasional pain in the joints the patient's general health has not retrogressed and her weight has not declined.

The difficulties attending the treatment of this case were increased by the fact that the patient would not receive a general anæsthetic, and that the serious nature of her disease had to be withheld from her knowledge.

Case 2.—F. P., *æt.* 50. In this case the breast had been amputated at an earlier date, but the growth had reappeared in the scar. When the patient came for treatment there was a very large mass of new tissue, "of the size of a cocoanut," on the front of the chest, in the region of the original scar. In November, 1913, the mass was treated by diathermy. A narrow-blade electrode was used and the growth cut away. The base and edges were then coagulated, a disc electrode being used. The coagulated tissue sloughed away and the skin began to grow over the denuded area. Eleven weeks later the only uncovered portion was a small area measuring about $1\frac{1}{2}$ inches in diameter. Signs of recrudescence were present in this part. The latter was coagulated by diathermy.

The patient wrote on February 11th, 1915, that is, fifteen months after the first application of diathermy, to say that the part was completely covered by smooth skin, except for one minute area, the size of a pin's head, from which a discharge occasionally appeared. There was no pain or swelling.

This case was under the care of Sir D'Arcy Power.

In the three remaining cases the affected breasts were completely occupied with malignant growth and the skin was adherent. Ulceration was present in one, and in another there were fungating masses. In all the cases the axillary glands were much enlarged.

In each case the entire breast was coagulated by diathermy. A disc electrode, 15 mm. in diameter, was used. After each stratum of tissue was coagulated it was cut away by the scalpel and the bleeding from severed vessels was stopped by the needle electrode.

Two of the patients were surprisingly free from pain and discomfort after the operation. The wounds commenced to heal. In one case the healing was nearly complete, the unhealed area measuring $1\frac{1}{4}$ inches by 1 inch. The patient then developed pneumonia and died. The other

patient left hospital when healing had proceeded to the same extent.

In the third case healing did not commence. Hæmorrhages were frequent and the patient died two months later. At the autopsy visceral metastases were found.

At a discussion on Surgical Diathermy held at the Royal Society of Medicine, in December, 1926, Mr. H. H. Rayner, surgeon to the Royal Infirmary, Manchester, stated that he had had experience of diathermy in cases of carcinoma of the breast that were plainly inoperable. The cases were of the type which presented massive growth either fungating through the skin or about to ulcerate through. Such cases were substantially benefited by diathermy. If there were no internal metastases and no massive enlargement of the axillary glands the patients lived an active life for two to three years.

At the same meeting Mr. Gordon-Taylor, surgeon to the Middlesex Hospital, gave his experience on the treatment of malignant disease of the breast. He described a very interesting case of advanced carcinoma mammæ which he had treated by diathermy three years previously. She had a horrible carcinoma of the breast which had been treated by herbalists and others. She summoned her doctor only because she had had alarming hæmorrhage. When she was brought to the nursing home she was nearly dead. Her breast was removed by diathermy, and she was transfused. There were no enlarged glands at the time. She recovered. Three years after the operation she was still well.

(*b*) *Eradicable Cases*

Some important work on the surgery of neoplastic disease of the breast has been conducted during the past four years by John Anderson, surgeon to the Royal Infirmary, Dundee. He has employed the so-called cutting-current to perform the function of the scalpel in the radical amputation of the breast. A description of the cutting-current and its action and uses have been given on p. 239 *et seq.*

Anderson has applied this arc electrode method for the

complete dissection in cancer of the breast, but he uses the ordinary scalpel for the small area immediately over the axillary vessels and nerves. The arc electrode is not used in the axilla for the following reason: it has already been stated that the excitable tissues are momentarily stimulated when the arc electrode makes contact with them or the tissue in close vicinity. The stimulation of the nerve trunks in the axilla causes jerking movements of the arm, and therefore the action of the arc could not be accurately controlled.

The bleeding which occurs from the *larger* vessels, after they are severed by the electrode, is stopped by coagulating their divided ends. This is done by making contact with the electrode on the forceps attached to the vessel, thus procuring diathermic coagulation. The wound flaps, which have been dissected back by the arc electrode, are closed in the ordinary way by suture and clips. *Healing by first intention occurs.*

Anderson finds that, on the whole, the healing is better than that which follows cutting with the scalpel. He feels convinced that the sealing of the lymphatics as they are dissected away greatly lessens the chance of recurrence. The results which he has obtained compare very favourably with those which he has secured by means of the ordinary scalpel. He finds that the new method has no disadvantages on comparison with the scalpel; in addition it has several advantages. The patient has much less pain and shock after the operation, less blood is lost and the body heat is maintained locally.

Anderson has employed the arc electrode in over eighty cases of malignant disease of the breast. Sufficient time has not yet elapsed to render possible a conclusive statement regarding the prolongation of life after the new operation, or the length of time of freedom from metastasis. It is not too much to say, however, that operation with the arc electrode marks a new advance in surgery, especially in that of malignant disease. In none of the cases which were seen at later dates were there local recurrences.

At the above-mentioned discussion on Surgical Diathermy Gordon-Taylor stated that he had used Anderson's method in

the treatment of fifteen cases of malignant disease of the breast during the past ten months. He said that the condition of the patients was good when they came off the operating table; and that the facility with which the bleeding could be stopped by applying the electrode was very striking and tended much to shorten the operation. He stated that the employment of diathermy held out considerable advantage over ordinary surgery with the knife.

4. Female Genitalia.

The author has treated twelve cases of malignant growth of the female genitalia by diathermy. All were too advanced for surgical excision. In ten cases the growth arose from the cervix uteri; in one from the vagina, and in another from the right labium majus and part of the left. In all of the cases of carcinoma of the cervix, the growth had spread into the pelvic cellular tissue, so that parts of it could not be reached from the vagina by the electrode: and in the regions where it had spread into the wall of the rectum or bladder, coagulation could not be produced for fear of injury to the latter organs. The most that could be expected was destruction of the primary focus and its subsequent replacement by granulation tissue and epithelium, so as to abolish hæmorrhage and discharge.

In all the cases, save one, the results of the operation were not satisfactory. The patients did not derive much relief of pain and the bleeding was not stopped. The best result was obtained in a case (described below) of inoperable cancer of the cervix and vagina.

S. S., *æt.* 55. In the situation of the cervix there was an ulcerated excavated mass, with hard and everted edges. The vaginal wall was involved posteriorly, and the posterior left fornix was obliterated completely. Definite induration extended to the pelvic wall and to the utero-sacral folds as far as the bowel. Diathermy was applied in August, 1913, to the parts of the growth that were accessible from the vagina. The patient left hospital nine days later. The slough had not then entirely separated, but the whole of the vaginal mass previously felt had entirely gone and the vaginal wall was covered with smooth tissue.

This patient came at intervals to the out-patient department, and no hæmorrhage or discharge was seen, and no ulceration. The induration previously felt in the pelvic ligaments remained. She was last seen in June, 1914 (ten months after the diathermy), and could not be afterwards traced.

Diathermic coagulation is of value in the preliminary treatment of operable carcinoma of the cervix, before the Wertheim operation, in place of an initial application of zinc chloride or formalin. It was applied to a case of carcinoma of the cervix on June 23rd, 1913. On July 1st a Wertheim operation was commenced, but could not be completed on account of the extensive spread of the growth within the pelvis. The part of the cervix to which the diathermy had been applied was found to be firm, like scar tissue, and no hæmorrhage was caused by its manipulation or incision, and there was no discharge. This patient lived till February, 1914.

J. D. Barris has treated a few cases of carcinoma of the cervix by diathermic coagulation prior to hysterectomy. In one of the cases a highly vascular fungating growth projected from the cervix into the vagina. The fungating portion and base were subjected to diathermy. The coagulated tissue sloughed away and hysterectomy was performed at a later date.

Nagelschmidt describes (*Lehrbuch*, 1st edition, p. 277) the excision of a uterus after diathermic coagulation of a carcinoma of the cervix. After laparotomy had been performed and the intra-abdominal part of the operation had been completed, a mass of bleeding new growth attached to the cervix was completely coagulated by diathermy applied *per vaginam*. The body of the uterus was grasped by the hand of an assistant so as to give warning of excessive heating of the part held and other parts in the abdominal cavity. This excessive heating, however, did not occur. After complete coagulation of the cervix the vagina was rinsed out and dried, and the uterus, with the remains of the cervix, were removed, as a sterile body, through the abdominal wound.

5. Skin.

(*a*) *Rodent Ulcer*

Diathermy is a therapeutic agent of great value in the treatment of rodent ulcer. It has proved its worth, not only in early cases, but also in those which are more advanced,

and in others which have resisted treatment by X-rays, radium, zinc ions or solid CO_2, or have recurred after temporary healing by one or another of these agents. The ulcers have healed, and smooth, soft, unwrinkled scars were left.

It is especially in cases in which cartilage or bone has been invaded that diathermy is of value. In cases of this kind, radium or X-rays are unable, in the experience of most workers, to destroy the malignant tissue. Diathermy, however, can destroy bone and cartilage just as easily as the soft tissues, and granulation tissue will grow over the site after the destroyed portion has separated.

Rodent ulcers of long duration in which a large amount of soft tissue and bone have been destroyed are difficult to arrest for long periods, although temporary healing can be effected. Recrudescent ulceration can again be treated by diathermy and healing will again occur. In this way the patient can be kept in comparative comfort and free from pain until death from asthenia occurs.

The author has treated, by diathermic coagulation, some cases of extensive rodent ulcer in which there was widespread destruction of skin and underlying tissues, and caries of bone. It is absolutely necessary, if any benefit is to be obtained from treatment by diathermy, that such cases should be seen not less frequently than once each month, and the treatment repeated directly recrudescence is seen or suspected. It is difficult to destroy all the malignant tissue at one operation, especially in regions where nearness of important structures compels cautious limitation of the diathermy.

After the first coagulation by diathermy, and the destruction of the edges and base, the ulcer is at first enlarged, but the raised, round, undermined edges disappear, and the borders of the ulcer assume a healthy appearance, and grow inwards. The size of the ulcer diminishes considerably and healing may occur, but recrudescence is very likely to take place and ulceration to recommence. Diathermy should then be reapplied without delay.

One of the cases which the author treated by diathermy had lost the front of the right cheek and the right half of the nose. The underlying bone had been extensively destroyed by the rodent ulceration, and a large cavity, bounded on the inner side by the nasal

septum, connected the nasopharynx with the exterior. A gland, removed from the submaxillary region, showed the presence of carcinoma. The ulcer had been previously treated by caustics, and later by X-rays, and had been rendered quiescent, except at the outer edge, where a small mass of growth had appeared. This was coagulated by diathermy in June, 1917, under local anæsthesia, and healing followed.

The patient came under the writer's care again a year later. Active ulceration was taking place at the edges. Diathermy was applied, under general anæsthesia. After the sloughs had separated, apparent healing took place, and epithelium grew over the edges. The upper lip was reduced in size, in the region of the angle of the mouth, to a small rounded cord, $\frac{1}{4}$ inch thick, and a narrow area of healthy tissue separated the inner canthus of the left eye from the adjoining edge of the ulcer. Shortly after this operation excision of the right eye had to be performed. It was of extreme importance for the patient that the ulcer should not extend towards the left eye; also that the narrow bridge of tissue which connected the upper lip to the right cheek should be kept intact.

In January, 1919, diathermy had to be applied again to part of the outer edge, and in April, 1919, to the nasal edge. In July, 1919, recrudescence was observed at the outer edge and diathermy was applied. Apparent healing took place after each treatment. Up to the time of the last operation the patient had been able to travel and attend to his work. Pain was frequently felt, but applications of ultra-violet rays were very effective in procuring relief. The patient did not regain strength or activity after the last operation, and he died in September, 1919.

It seems, in this case, that diathermy delayed the progress of the malignant ulceration. During the patient's lifetime, the ulcer approached no nearer to the opposite eye, whilst the small shred of tissue, which was all that was left of the upper lip in the region of the angle of the mouth, remained intact to the end of the patient's life.

Dr. Gray, dermatologist to University College Hospital, has kindly allowed the writer to refer to this case, which had formerly been under his care.

A case which illustrates the power of diathermy to heal a carcinomatous rodent ulcer accompanied by destruction of bone and cartilage is described below. Radium and X-rays had failed to arrest the ulcer.

Case 21.—W. D., *æt.* 39. This patient originally suffered from a rodent ulcer of the right cheek. It was treated by X-rays and healed temporarily. Afterwards it reappeared and gradually increased in size in spite of further treatment with X-rays and, later, with radium. On July 2nd, 1914, the ulcer had extended forwards on to the cheek, one inch in front of the external auditory meatus and backwards on to the pinna. Part of the latter had been destroyed.

On the day mentioned the base and edges of the ulcer were coagulated, including the eroded edge of the pinna and its cartilage, and the bone at the base of the ulcer. The patient was kept in hospital until healing was complete. Three months were occupied in the

separation of the destroyed tissue and the subsequent healing. The latter process was certainly rendered possible and aided by the daily dressing and prevention of sepsis.

Four months after the operation the appearance was that depicted in Fig. 67. There was no ulceration or swelling, and the new anterior edge of the pinna had healed.

An enlarged gland was then excised from the neck. It was found to contain carcinoma cells.

This patient was last seen nine months after the diathermy. There was then no sign of recrudescence. The subsequent fate was not ascertained.

Fig. 67.—W. D. Case of carcinoma of cheek and pinna. Ulcer healed after diathermic coagulation.

Cases of rodent ulcer in which bone and cartilage have not been invaded can be healed by diathermy even if treatment by zinc ions and X-rays are without effect. In the case described below no recrudescence had occurred three and a half years after diathermy. An illustration of the ulcer before the treatment is shown in Fig. 68. Fig. 69 shows the appearance two and a quarter years later. The patient was last seen three and a half years after the treatment and the healing had remained perfect.

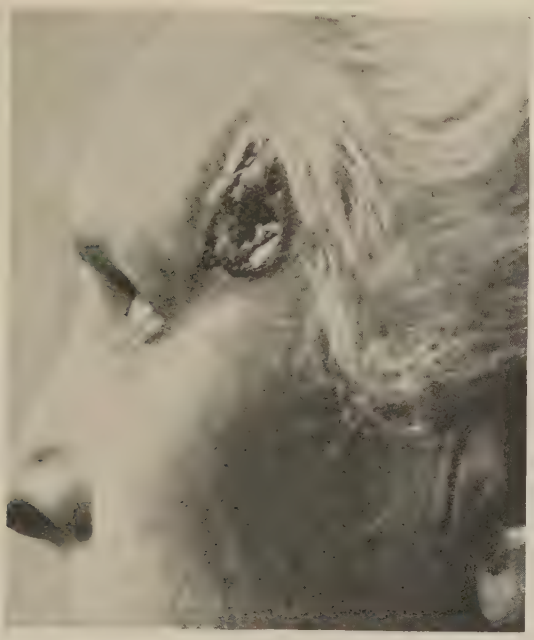


FIG. 68.—E. B. Rodent ulcer of temple. Before treatment by diathermy.

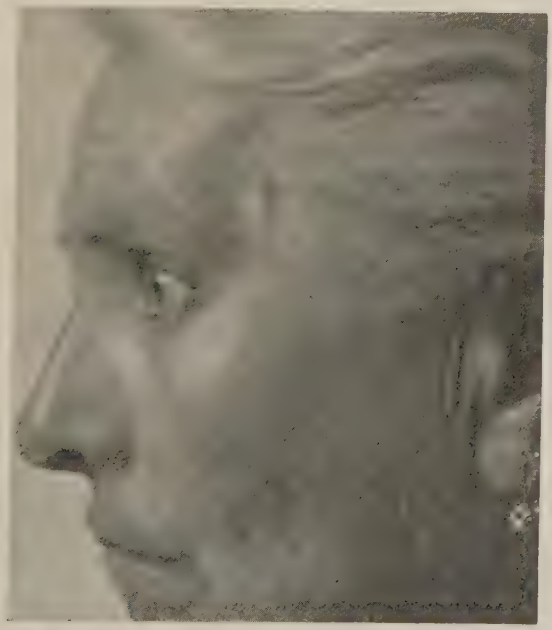


FIG. 69.—E. B. Same case as that shown in Fig. 68, after diathermy. No recrudescence was observed 3½ years later.

E. B., *æt.* 64. This patient had had an ulcer in the left temporal region. An ulcer in this region had been noticed sixteen years previously. It had been treated by zinc ions by the late Dr. Lewis Jones and healed. In 1917 ulceration of the same region recommenced. X-ray treatment was applied and the ulcer healed partially. It then enlarged in spite of further treatment by X-rays.

In 1918 the edges and base were coagulated by diathermy, under general anæsthesia. The ulcer healed, but a small nodule was noted two months later at the upper edge of the scar. This was coagulated by diathermy under local anæsthesia. Healing followed and there was no reappearance of nodules or ulcers for fourteen months. A small superficial ulcer then appeared. This was coagulated by diathermy. No further treatment was required.

Fig. 70.—S. S. Case of carcinoma of scalp. The photograph was taken five years after treatment by diathermy. It shows a bare area of bone. Scar tissue afterwards grew over the latter, and when the patient died, nearly 12 years later, the bone was almost completely covered and there was no evidence of malignant disease.

A case of rodent ulcer which had been kept under observation for eight years and has required no repetition of diathermy is described below. The histological structure was that of rodent ulcer becoming carcinomatous. Treatment by zinc ions and X-rays had been ineffective.

S. S., *æt.* 55. This patient had an ulcer measuring 1 inch by 1 inch on the right frontal region of the scalp. Its edges were raised and everted. Its histological structure was that of rodent ulcer becoming carcinomatous. Treatment by zinc ions and X-rays had proved ineffective. The chief symptom was incessant and severe pain. The ulcer was coagulated by diathermy on April 14th, 1914. The pain was greatly relieved. The destroyed tissue sloughed away, leaving an area of bare bone measuring 1½ inches by 1⅛ inches. In

July, 1915, the area of bare bone had increased to 2 inches by $1\frac{3}{8}$ inches. The soft tissues at the edges were tender but not hard or infiltrated. Some pus was seen at the edges. The patient complained of "attacks of pain like neuralgia." She refused further treatment. In October, 1916, the condition was unchanged. In May, 1919, a plate-like piece of bone had apparently separated. It was easily removed manually, and a bony area measuring $1\frac{7}{8}$ inches by 1 inch was uncovered. Dry scabs were present at the edges. The soft tissues were dry and not infiltrated.

Fig. 70 shows the appearance of the region, formerly occupied by the ulcer, on May 30th, 1919.

On August 3rd, 1920, the patient wrote to say that she felt quite well and had had very little pain during the last year. She came to the hospital in September, 1920. The bare area of bone was then partly covered by scar tissue.

The author showed this case at a meeting of the Section of Surgery of the Royal Society of Medicine in April 1922. The bare area of bone was then nearly completely covered by scar tissue. The patient died on January 16th, 1926, after a week's illness, due, according to the report, to bronchitis. It was stated that one spot of bare bone remained and that it had been painful for some months before the patient's death and had discharged.

(*b*) *Squamous-cell Carcinoma*

Squamous-cell carcinomata of the skin are no less suitable for electro-thermic methods of treatment than those of the basal-cell type (rodent ulcer). In its early stages the treatment by solid carbon-dioxide, radium or X-rays has its advocates and cures seem to have been effected. In advanced cases diathermic coagulation is more effective.

An interesting case is that of a gentleman who had an ulcer of his left cheek, measuring $\frac{5}{8}$ inch by $\frac{3}{4}$ inch and about $\frac{1}{4}$ inch deep. Its edges were raised and hard. It had been first noticed about a year ago. He stated that he had had a similar ulcer on his right cheek fifteen years ago, that it had been healed by the late Dr. Lewis Jones by means of zinc ions. In view of this the writer treated the ulcer on the left cheek by the same method, but without success. Diathermic coagulation was then effected (July 8th, 1920). Complete healing was not produced until another application of diathermy had been made (September 23rd, 1920). In December, 1920, the ulcer was completely healed. A ridge of keloid appeared in the scar. In July, 1921, there was no ulceration. The keloid had diminished and the scar tissue elsewhere was soft.

He died of old age in 1926, and his medical attendant told the writer that there had been no return of ulceration before death.

The case shown in Fig. 71 was one of slowly growing carcinoma of the skin in a woman of 63. A small "sore" had appeared on the front of the chest in 1913. It was treated by zinc ionisation and healing occurred. Later the

sore reappeared and could not be made to heal under treatment by zinc ionisation or by X-rays. When the patient came under the writer's care, in September, 1922, there was a fungating mass of growth measuring $3\frac{1}{2}$ in. by 4 in. The appearance was that shown in Fig. 71. Under general anæsthesia the growth was coagulated by diathermy. A month later the slough had separated. Healing commenced and was nearly complete at the end of November, 1922. A small area measuring 1 in. by $\frac{3}{4}$ in. refused to heal. It was treated by diathermic coagulation and healing occurred. Fig. 72 shows the appearance in July, 1923. A small scab-

FIG. 71.—K. B. Carcinoma of skin.

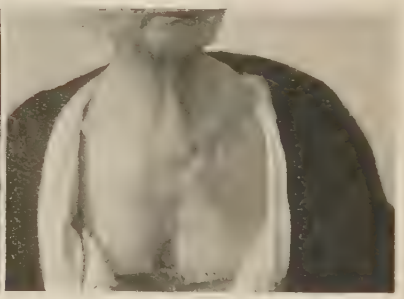


FIG. 72.—Same case as that shown in Fig. 71, ten months after treatment by diathermic coagulation.

covered ulcer was present near the centre of the scar. It did not heal completely, and diathermy was reapplied in January, 1924. In July and December, 1924, small recrudescent ulcers were treated by the same method. In May, 1925, another small ulcer, which had reappeared, was subjected to diathermic coagulation. The major portion of the scar which replaced the tumour remained free from return of growth up to the present time (January, 1927).

The histological appearance of the growth was that of carcinoma.

(c) *Epitheliomata developing in Scars*

Good results have been obtained by various workers in the treatment of epitheliomata which have developed in scars. In the case described below a massive malignant growth was coagulated by diathermy. Healing occurred and there was no return seven years later.

J. C., male, was admitted to St. Bartholomew's Hospital on September 17th, 1919, when he was 48 years old, under the care of Mr. J. H. Roberts, assistant surgeon to the hospital. When a child the patient received a large burn on the upper part of the right thigh and the adjacent part of the abdominal wall. Twelve months before admission an ulcer developed in the scar and increased in size. On examination, after admission, a large contracted scar was seen, and the hip could not be fully extended. A large fungating mass measuring 5 inches by 5 inches was seen in the right groin. It extended almost to the pubes. There was induration around. A section showed epithelioma.

On October 10th, 1919, the mass was coagulated by diathermy. On October 31st, and again on December 5th, 1919, some nodules which had escaped destruction were coagulated. On January 8th and March 3rd, 1920, skin from the left thigh was grafted on the wound.

On February 11th, 1927, the patient was well and the scar showed no signs of malignant growth.

The writer is indebted to Mr. Roberts for permission to publish this case.

(*d*) *Roentgen-ray Keratoses and Epitheliomata*

These appear to be particularly suitable for treatment by electro-thermic methods. Prof. Bordier,[1] of Lyons, treated some keratoses on his own fingers by diathermic coagulation. Permanent healing was the result. Another which was not treated became painful and an ulcer formed. The latter had the clinical characteristics of a malignant ulcer. It was treated in the same way. It healed in two months and there was no recurrence in two years.

G. E. Pfahler,[2] of Philadelphia, wrote that he had removed at least a hundred small keratoses from his own hands and that they had not reappeared. One was removed surgically in 1912 and shown to be malignant. Recurrence took place, but it was successfully treated by electro-coagulation.

(*e*) *Lupus X-ray Epitheliomata*

Coagulation by diathermy is a valuable method of treatment of epitheliomata which have developed in lupus after prolonged X-ray irradiation. Speaking on the subject at the Royal Society of Medicine on December 17th, 1926,

[1] *Paris Med.*, 1922, XII., Part 2, 469.

[2] *Amer. Jour. of Roentgenology and Rad. Therap.*, N.Y., 1925, XIII. 41–48.

H. H. Rayner said that cases could be satisfactorily treated by ordinary surgical measures in their early stages. In advanced cases diathermy gave better results, both in regard to economy in surgical interference and in respect of the ultimate result.

A case is now under treatment by the writer. The ulcer which formerly occupied the greater part of the right cheek is now about half the original size.

Part V

NON-MALIGNANT GROWTHS AND OTHER FORMS OF MORBID TISSUE

In the treatment of certain kinds of non-malignant growth the electro-thermic methods yield results better than those obtained by the knife. The power of the diathermy current to coagulate tissue *en masse* without disturbing its anatomical continuity or that of its vessels may be utilised with advantage in the treatment of highly vascular neoplasms such as fibromata of the nasopharynx and angiomata. Neoplasms of this kind can be destroyed without loss of blood.

Ulcers and granulomata caused by infection are especially suitable for treatment by diathermic coagulation, not merely for the reasons stated above, but for the fact that the infecting organisms are destroyed within the coagulated tissue. The permanence of the result of treatment of papillomata of the urinary bladder by diathermic coagulation may perhaps be due to the sterilisation of the growths as they are destroyed.

It has already been mentioned that the scar tissue which replaces morbid tissue after coagulation of the latter by diathermy does not shrink or form adhesions with parts in contact. For this reason diathermy is of value in removing or dividing bands of scar tissue, such as synechiæ, and in freeing adherent organs such as the tongue when bound to the floor of the mouth after scalpel operations.

Diathermic coagulation can be successfully employed for the purpose of sealing bleeding points on the lip, nasal

septum, etc. In this way hæmorrhage has been permanently stopped.

It is likely that the future will see the use of electrothermic methods in the treatment of growths and granulomata which, at the present day, are treated by the scalpel or hot metal or chemical caustics. Except where otherwise stated the following pages will be reserved for the consideration of those diseases or cases in which the electrothermic methods, in the hands of experienced workers, have procured better results than those obtained by simpler methods.

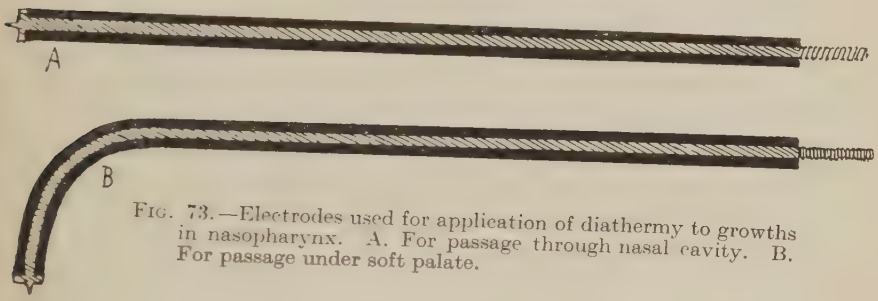


FIG. 73.—Electrodes used for application of diathermy to growths in nasopharynx. A. For passage through nasal cavity. B. For passage under soft palate.

Upper Air Passages.

Fibromata in the Nasopharynx.—The severe and sometimes fatal hæmorrhage which accompanies excision of these growths renders the use of the knife dangerous. A case was treated by diathermic coagulation at St. Bartholomew's Hospital by Mr. Rose, who kindly allowed the writer to report it. The active electrodes which were used were specially designed for the purpose. They are shown in Fig. 73. They consist of ebonite rods, 4 mm. in diameter and 10 cm. in length. They contain metal cores for conducting the current. One end of the metal is screwed into a handle (not shown in the figure). The other end terminates in a metal disc which bears a very short point. This point serves to anchor the free end of the electrode and prevent its movement off the surface of the growth. The straight electrode approaches the growth through the nasal cavity. The curved electrode reaches it from under the soft palate.

These electrodes were devised because the single-needle electrode which was used on the first occasion punctured the growth and caused profuse hæmorrhage.

J. S., *æt.* 14. A fibroma of the nasopharynx had been removed by the knife on a previous occasion, but it had recurred. Diathermy was then employed. The first attempt was a failure for the reason stated above. On the second occasion the electrode shown in Fig. 73 (A) was used. It was applied in succession to different parts of the surface, and the current was directed through various regions of the growth. The current attained a value of 1·2 amperes and was allowed to pass for thirty seconds at each application of the active electrode.

Two months later the diminution in size of the growth was evident. A second series of applications was made.

Four months after the second operation a third series was made, the growth being approached from under the soft palate. The remains of the growth sloughed away almost completely after the third operation, and when the patient was last seen (one year afterwards) there was a very small remnant visible and the symptoms of obstruction had disappeared.

The patient did not stay for more than two or three days in hospital after each operation, and there was no rise of temperature, except on one occasion, when it reached 100° F. There was no post-operative shock on any occasion.

Teratoma. By means of his diathermy snare electrode (see Fig. 74) Broughton Barnes removed a teratoma from the nasopharynx in a boy aged 5 months.

The tumour was $1\frac{3}{4}$ in. long, and a little more than $\frac{1}{2}$ in. broad at its maximum diameter. It arose apparently from the sphenoid. The upper inch consisted of a long pedicle about as thick as a slate pencil. The body of the tumour normally lay in the hypo-pharynx, but was occasionally hawked up into the mouth. It was pink in colour and covered by normal skin bearing copious fine whitish down.

Under general chloroform anæsthesia the tumour was pulled up into the mouth by a pair of Spencer Wells forceps and the snare was threaded over it, passed into the nasopharynx and pressed against the sphenoid. The current was started and the pedicle severed. The tumour came away in about 10 seconds. There was no hæmorrhage. Owing to the very small space available there was slight scorching of the soft palate, and the baby had slight œdema of this part for 48 hours. Five months later there was no sign of recurrence.*

The snare electrode designed by Broughton Barnes for the removal of post-nasal growths is shown in Fig. 74. It is made of vulcanite. The broader portion contains a metal liner. The cable from the diathermy machine is screwed

* The writer is indebted to Mr. Broughton Barnes for details of this case and for permission to publish them.

into the lower end of the liner. The liner contains a hollow metal slide which can be made to move along the liner. The wire, which is made of hard-drawn silver, is passed through the stem and its ends are gripped in the slide by a vulcanite-headed screw. The head of the screw projects through a slot, thereby enabling the operator to draw the slide into the liner and pull the wire loop into the stem of the electrode.

The cable is screwed into the liner and connected to the diathermy machine. The circuit is completed by an indifferent electrode which is applied to some convenient part of the body and connected by a cable to the other terminal of the machine. The current passes along the liner, the slide and the wire to the loop which projects from the free end of the stem, and enters the tissue where it is grasped by the wire loop. It passes to the indifferent electrode. The tissue in contact with the wire loop is coagulated. As the wire is drawn into the stem the coagulated tissue is cut through. The operation is one of combined coagulation and cutting, and if the wire is drawn with sufficient slowness the tissue in advance of it will be coagulated before it is cut.

Fig. 74.—Diathermy snare electrode. (Made by Watson & Sons.)

Synechiæ.—When adhesions between the septum and lateral wall of the nasal cavity are divided by the knife or hot metal they are liable to form again unless the parts are separated artificially until healing occurs. Dan McKenzie recommends the treatment of the synechiæ by diathermic coagulation. He says that the reaction is trifling and often absent, and that there is little or no tendency to the recurrence of the adhesion. There is no need, therefore, to maintain an objectionable foreign body in the nasal cavity during the process of healing.

Angiomata.—Coagulation by diathermy is a particularly efficient form of treatment for angiomata of the tongue, lips, pharynx and buccal mucous membrane. They can be destroyed usually at one sitting, even if they are of large size. After healing it is sometimes difficult to realise that any operation has been performed.

The following case (E. G.) is a good example of the power of diathermy. Surgical treatment was considered inadvisable and electrolysis had failed. It is of interest as it was the first in this country to which diathermy was applied for surgical purposes. It was one of the three treated by Nagelschmidt at St. Bartholomew's Hospital on October 21st, 1910.

E. G., *æt.* 17. A large pulsating nævus was present on the right side of the tongue and floor of the mouth. A general anæsthetic was given and the nævus coagulated by diathermy. There was no loss of blood. A large slough formed. It separated ten days later and healing was complete four weeks after the operation.

Four years later (October, 1914) the patient came to hospital again, saying that she had noticed some patches of nævus in her mouth. On examination it was seen that there was a small mass of nævus, the size of a small bean, on the right side of the tongue, and two small patches of nævus, one on the tonsil, the other on the wall of the pharynx. Except for the patch of nævus the tongue and floor of mouth in the situation of the original nævus were quite normal in appearance.

On October 7th, 1914, the nævus on the side of the tongue was transfixed with the single-needle electrode and coagulated under local anæsthesia. The slough separated, and by October 26th the part had completely healed, leaving no trace of nævus. The other patches were treated similarly, with equally good results.

A number of cases of nævus of the tongue and lips have been treated by the writer by diathermic coagulation. Multiple-needle electrodes were used and the current was increased until the tissue whitened from coagulation. There was no bleeding during the operations or afterwards. Soft pliable scars were left on the lips. In the tongue cases a close inspection was necessary in order to detect any difference between the part originally subjected to diathermy and the adjacent regions.

A photograph of one of the cases is reproduced in Figs. 75 and 76.

The following case illustrates the potency of diathermy in preventing recurrent bleeding after other methods have failed.

E. L., *æt.* 17. (Mr. Harmer's case.) This patient had an extensive nævus in the right wall of the nose, in the skin and mucous membrane. She had suffered from severe hæmorrhage from the nose on different occasions, and had been under treatment at intervals since the age of five. The facial artery and the external carotid artery had, on different occasions, been ligatured, but without avail. During some of the attacks the hæmorrhage was furious, leaving the patient nearly completely blanched. One of these attacks occurred in hospital and was actually seen. The last attack occurred in May, 1914, and the blood escaped from a channel in the septum in the region of the septal artery. The hæmorrhage was temporarily stopped by pressure. The part was then coagulated by diathermy (in May, 1914). During the following years the patient had no further attacks of hæmorrhage.

Bleeding Points in Nose and Lips.—Bleeding points can be immediately sealed by means of diathermy. In the case

FIG. 75.—Cavernous angioma of upper lip.

FIG. 76.—Same case as that shown in Fig. 75, after diathermic coagulation of angioma. Soft scar was left, and no evidence of angioma after four years.

of the lip a single-needle electrode is inserted for about one-eighth of an inch through the mucous membrane at the point from which the blood is escaping. The current is gradually increased from zero until coagulation is first noted. It is then switched off. It must not be allowed to pass for a longer time because the tissue in contact with the needle will dry and become adherent to the metal. If this happens the withdrawal of the needle will bring away adherent tissue and bleeding will at once start afresh.

In the case of the nasal septum a ball electrode of the smallest size should be used. The current should be stopped at the moment when coagulation is first noticed. If it is allowed to pass for a longer time coagulation will proceed

to a greater depth and the septum may be perforated. The same event may occur if a needle electrode is used.

The heating of tissue accelerates and increases the circulation through it, and if the coagulation caused by the diathermy is insufficient, the bleeding will start afresh after removing the electrode. If this occurs the bleeding may be stopped temporarily by fulguration, as advised by Dan McKenzie. By lifting the active electrode a short distance from the bleeding point the sparks will pass on to the latter. An adherent cake of charred blood will form. This is "sufficient to cover the bleeding vessel with an adherent cake of charred blood, after which the more deliberate coagulation of the area may be proceeded with" (Dan McKenzie).

Three cases of persistent bleeding from the lower lip were treated by the writer by diathermy. The hæmorrhage stopped at once. There was no recurrence during the periods for which the patients were kept under observation, and it may be concluded that the results were permanent. One of these cases was in an old lady who had been rendered considerably anæmic by loss of blood. She came with her doctor during an interval of freedom from hæmorrhage. A zinc needle was inserted into the lip and a galvanic current was passed, the object being to seal the opening by means of zinc ions and the formation of insoluble albuminate of zinc. After withdrawal of the needle, however, there was a copious outpouring of blood. It was controlled by pressing the lip between the fingers while the preparations were made for diathermy. A single-needle electrode was inserted and the tissue around it coagulated. The pressure was cautiously relaxed and four eyes gazed anxiously at the lip. Bleeding did not occur and the subsequent history showed that the opening had been permanently sealed.

Lupus and Tuberculous Ulcers.—In the treatment of lupus of the mucous membranes in regions where the local application of ultra-violet light is impossible, Dan McKenzie thinks that diathermy may be applied with advantage, and he regards it as superior to curettage and chemical caustics. He has noted, in many cases, the appearance of new nodules in the apparently healthy tissue adjacent to that in which

the lupus was destroyed. This phenomenon is noticed also after the treatment of lupus nodules in the skin. Considerable patience is necessary, therefore, and the local treatment by diathermy should be supplemented by general application of ultra-violet rays to the skin.

The following case is one of tuberculous ulcer of the nasal septum. It healed after diathermic coagulation when treatment by other methods had failed. Although ulceration recommenced at later dates it was always healed by further applications of diathermy.

The patient, an adult male, had a tuberculous ulcer on the lowermost part of the nasal septum and the adjoining part of the upper lip. It measured $\frac{3}{4}$ inch by $\frac{1}{4}$ inch. A small granuloma was present immediately above the ulcer. The base and edges of the ulcer and the granuloma were coagulated, after procuring local anæsthesia. A single-needle electrode was used and the morbid parts, together with the healthy tissue at the edge, were coagulated piecemeal.

The coagulated parts sloughed away and the residual ulcer healed. Four months later a minute ulcer was noted by the patient on the septum in the uppermost part of the scar. This was coagulated by diathermy and healing took place. Nine months later a very small ulcer was seen in the same situation. Elsewhere the scar was healthy. The recurrent ulcer was again coagulated by diathermy. The portion of the scar on the lip remained healthy since the first coagulation, *i.e.* for a period of thirteen months. The ulcer had received several applications of ionisation but could not be made to heal. The patient suffered from quiescent pulmonary tuberculosis.

In a communication to the writer W. J. Harrison, of Newcastle-on-Tyne, described some good results which he had obtained in the treatment of lupus of the palate, pharynx and fauces by diathermic coagulation. In the case of the posterior pharyngeal wall he uses a small disc electrode and moves it over the affected region while the current is passing. The lupus nodules appear to be destroyed by a less high degree of heat than the normal tissue.

Adherent Soft Palate.—Two cases of adherent soft palate, one in a boy of 7, the other in a man of 25, were treated by Douglas Harmer by diathermy. By means of a blade electrode the adhesions were divided and the palate freed. The adhesions re-formed and no improvement was effected.

The failure was possibly due to the fact that the parts were allowed to remain in contact during the healing of the ulcers which were left after the separation of the sloughs.

Further trial should be given to diathermy, and the precaution mentioned should be observed.

Dan McKenzie has employed diathermic coagulation as a means of reopening the nasopharynx and posterior nares after they have been more or less obliterated by scar tissue after luetic ulceration. The treatment proved to be no more successful than the older methods (*Acta Oto-Laryngologica*, Vol. VII., fasc. 4, p. 589).

Enlarged Tonsils.—Diathermy has been employed for the removal of enlarged tonsils by a few laryngological surgeons in this country. The method which they employed was the combined coagulating and cutting operation. This operation, in a case of enlarged tonsils, was demonstrated by Nagelschmidt, at St. Bartholomew's Hospital, in October, 1910. In August, 1913, the writer coagulated the tonsils of a girl, aged 17, by means of a multiple-needle electrode. The neck became much swollen soon after the diathermy, but the patient did not suffer much discomfort, and the swelling subsided completely. After separation of the slough it was found that the tonsils had not been completely destroyed, although it appeared at the operation that coagulation of the entire mass had occurred. A general anæsthetic was employed during the operation.

In 1913, H. D. Gillies operated on the tonsils of three children aged, respectively, 7, 4 and 14. In the first case the tonsils were transfixed at the bases by a single-needle electrode. In the other two the blade electrode was used and the combined coagulating and cutting operation performed. There was no bleeding during the operations. The patients did not complain of pain or difficulty in swallowing. In one case there was slight bleeding the day after the operation.

In a discussion on Surgical Diathermy (v. *Proc. Roy. Soc. Med.*, Vol. XI., No. 9, Section of Electrotherapeutics), Dan McKenzie stated that he had destroyed enlarged tonsils in adults, leaving intact faucial pillars and a smooth scar. There was no hæmorrhage.

Writing in the *Acta Oto-Laryngologica* (Vol. VII., fasc. 4) the surgeon above-mentioned stated that he had, on more than one occasion, used simple dissection for one tonsil and

diathermy dissection for the other, and had found that, after healing, it was impossible to distinguish any difference between the two cicatrices.

The combined coagulating and cutting operation seems to have been the only method of employing diathermy which has been practised by laryngological surgeons in this country for the removal of tonsils. There are, however, at least two other methods available. In one of these the tonsil is coagulated in different parts by means of a single-needle electrode. In the other fulguration is practised. These operations seem to be widely employed in the United States. They are performed under *local* anæsthesia in adults.

The author was present at a lecture-demonstration by Dr. Raymond Elmer at Chicago, in November, 1925, on the treatment of enlarged tonsils, by the first of these methods. Below is given a brief *résumé* of the lecture.

Dr. Elmer said that he used, for procuring local anæsthesia, half per cent. of novocaine to which are added 5 grains of sodium chloride and 5 grains of magnesium sulphate to the ounce. One drachm is injected *behind* the tonsil at about the centre of the posterior pillar. If the tonsil is submerged double the quantity of quarter per cent. solution is injected so as to bring it more into view. Gagging can be prevented by swabbing the throat with 4·4 per cent. solution of cocaine. By means of a wooden spatula the tongue is depressed. The active electrode, which is of the single-needle type, is inserted into the centre of the tonsil. By means of a foot switch the current is started and allowed to flow until the surface is seen to blanch from coagulation around the needle. The machine should be adjusted so as to give not more than 500 ma. In most cases 350 ma. are sufficient. About seven separate punctures are necessary in order to coagulate the entire tonsil. There usually remains uncoagulated a portion of tonsillar tissue which lies buried under the anterior pillar of the fauces. By inserting the needle behind this pillar into the tonsil the latter can be readily brought into view and coagulated.

After the operation the patient is told to go home and remain indoors for two days. He can consume ordinary meals. He feels little discomfort. The addition of the magnesium sulphate to the anæsthetic has the effect of prolonging analgesia for a number of hours, thus giving the acute reaction time to subside.

On the third day after the operation the slough begins to soften and separate. Under no circumstances should it be removed artificially, as bleeding will occur. The slough is completely separated on the tenth to the twelfth day, and healing is complete on the fourteenth or fifteenth. During the sloughing the patient may resume his occupation and he feels very little discomfort.

Dr. Elmer stated that he had treated over 500 cases during $2\frac{1}{2}$ years, the youngest patient being 15 and the oldest 85. In this series fifteen suffered from secondary hæmorrhage, due, the lecturer thought, to premature separation of the slough. In most of these the bleeding

was stopped by ordinary hæmostatic solutions. In two it was necessary to apply diathermy. Some severe œdema followed the treatment of the first twenty cases. This was due, the lecturer said, to the use of currents stronger than 500 ma., and to the injection of the anæsthetic into the tonsil instead of behind it. There was no fatality, no pulmonary abscess, no pneumonia, no otitis media and no severe hæmorrhage.

Dr. Elmer entitled the treatment "electro-coagulation."

The second method of treating enlarged tonsils is that of fulguration. Surface anæsthesia is procured and the sparks are directed on the entire surface of the tonsil. Special directors are used which prevent the sparks passing elsewhere than desired. The superficial layers of the tonsil are desiccated at each application. The entire tonsil cannot be destroyed at one sitting. The operation is repeated every two or three weeks until the whole of the tonsillar tissue has been removed. In the other form of operation described the entire tonsil is coagulated at one sitting.

2. Skin.

Lupus vulgaris.—The use of diathermy for the destruction of lupus was described by Nagelschmidt in 1910 (*Zeitschr. f. ärztl. Fortbild.*, 1910, No. 24). In his *Lehrbuch* illustrations are shown of six cases before treatment, and after treatment and subsequent healing (*Lehrbuch der Diathermie*, 1st edition, pp. 298–303).

In one case there were several nodules behind the ears, and on the cheeks of both sides and under the chin. One application of diathermy was made under general anæsthesia. After healing, a smooth scar was left, and it is stated that there was no reappearance of lupus. Judging by the photograph, the result was excellent.

In another case there were lupus nodules on the right cheek, inside and outside the nose, fistulæ, and abscesses at the edge of the mandible. The same case, four years after treatment by diathermy, showed scars in the site of the original disease and no apparent nodules. In another case, tuberculosis had affected the skin and bone of the thumb. In spite of amputation, there was recurrence on the stump and the skin of the hand. The lesions were destroyed by

one application of diathermy and no recurrence was noted as late as four years after.

Details of the cases and of the method of applying the diathermy are not given in the *Lehrbuch*.

The author has obtained succesful results by means of diathermy in cases which had resisted other methods of local treatment or had improved up to a certain stage without healing. No recurrence was noted during the periods when they were kept under observation. The longest periods of observation were six and seven years. (See below, Cases A. R. and M. J.)

The nodules may be treated either by coagulation or by fulguration. The local reaction after fulguration is less than that after coagulation, and the healing is quicker. On the other hand, there is less likelihood of particles of tissue escaping destruction when the diathermy current is used to coagulate than when it is employed for the purpose of fulguration. In adults fulguration can usually be practised without an anæsthetic, local or general, if the nodules are not large. Coagulation, as a rule, cannot be practised thoroughly unless an anæsthetic is administered. In actual practice fulguration should be tried first.

The cosmetic results are excellent, both after coagulation and fulguration. Soft smooth scars are left. Keloid may develop in the scar. It may be prevented by applying pyrogallic ointment to the ulcer after the coagulated or desiccated tissue has separated.

Below are given the particulars of two cases which have been kept under observation for the longest periods.

A. R., female, aged 40. A number of nodules were present in the skin over the right maxilla. They had been treated for a long period by ultra-violet rays from a tungsten arc lamp. No apparent difference was observed. On February 11th, 1919, one of the nodules was coagulated by diathermy. A single-needle electrode was passed into the centre and the current very slowly increased until the coagulation reached the boundary of the nodule. The coagulated tissue sloughed away, leaving a small ulcer, which healed after ten days. The remaining nodules were treated in a similar manner at later dates in the same year (March 28th, May 27th, June 24th, October 14th). After healing there remained smooth scars. A patch of keloid developed on the scar left after the first ulcer had healed, but not on the other scars.

On April 6th, 1920, the scars appeared healthy, but a fresh nodule was present. This was treated in the same way.

On September 9th, 1921, four minute nodules were apparent at the periphery of the region formerly affected. These were treated by fulguration. The patient reported at intervals during the succeeding years. No fresh nodules were seen. She was last seen in June, 1925.

M. J., female. This patient first came under the author's care in January, 1919, when she was 15 years old. There was a nodule of lupus measuring $\frac{1}{4}$ inch in diameter on the right shoulder. There were also groups of smaller nodules in the skin over the right wrist, the lower part of the left deltoid and the right side of the nose and adjoining part of the cheek. Treatment by X-rays had been given at long intervals over a period of two years and some improvement had been effected. She was then sent to the writer for local treatment by ultra-violet light. The affected areas were submitted to radiation from the tungsten arc lamp, after application of salicylic acid plasters. The single nodule on the right shoulder, however, was excluded from the treatment until August, 1919, when it was subjected to diathermic coagulation, under local anæsthesia. A single-needle electrode was used, the nodule and surrounding skin for a short distance were coagulated. At the present time (seven years later) there is a soft smooth scar.

Treatment of the remaining nodules by ultra-violet light was continued. Progress was made, but very slowly. From time to time a nodule was selected from one or another of the groups and treated by diathermic coagulation or fulguration. These nodules had the benefit of both forms of treatment, and the disease disappeared much more quickly than was the case with the nodules that received the ultra-violet rays alone. Healing occupied from two to three weeks.

Large nodules may require two or more applications of diathermy. In these cases it is sometimes found that the scar which replaces the originally infected tissue is not entirely free from lupus. Minute nodules are sometimes seen, too, in the skin around the scar. Repetition of the treatment is then necessary until all the nodules disappear. Repetition of the treatment does not alter the final appearance of the scar.

Ultra-violet light is a valuable ally to diathermy in the treatment of lupus. It accelerates healing of the wounds left after destruction of the nodules and increases the natural therapeutic powers of the body.

When treating cases of lupus it is a good plan to combine both forms of treatment. The number of applications of diathermy can then be reduced. A boy of six, who had several nodules of lupus in the cheek, side of nose, upper eyelid and eyebrow, with secondary infection of the skin, was sent to the Electrical Department of St. Bartholomew's

Hospital by Dr. Adamson, under whose care he had been in the Dermatological Department.

Ultra-violet rays from a tungsten arc lamp soon removed the secondary infection, but had no effect on the lupus. The patient was then given a general anæsthetic and some of the nodules were treated by diathermy, some being coagulated, others fulgurated. After healing of the wounds some fresh nodules were seen around some of the scars. The operation was repeated and some more of the original nodules were treated as well as the new ones. The operation was again repeated on a third occasion. In the hope of avoiding further operations the patient was subjected to local and general ultra-violet light treatment. The patient improved more rapidly under the additional treatment.

Considerable experience in the treatment of lupus by diathermy has been obtained by Dr. A. E. Milner. He employs the operation of fulguration and prefers to treat the patient under general anæsthesia. Up to January, 1924, he had treated 60 cases. Cures were obtained in 42 cases. One operation only was necessary in 5 cases. Two operations were needed in 5 cases. The average number of operations performed on the cured cases was 3·5.

Dr. Milner's cases included those in which the mucous membranes were infected as well as the skin. Re-infection of the latter is likely to take place unless the former are subjected to diathermy. The situation of the infected mucous membrane may render diathermy impossible. Dr. Milner does not undertake the treatment of cases unless every part of the diseased surface is accessible to fulguration.

Tuberculous ulcers should be treated by diathermic coagulation. Healing will take place and soft scars will be left. Ulceration will probably reappear later on if the mucous membranes are infected and not subjected to treatment. It is a good plan, in these cases, to subject the patient to general irradiation with ultra-violet rays. The following case of tuberculous ulcer was treated by diathermy and remained, healed for long periods, although the ulceration reappeared at later dates. General irradiation was not practised in this case.

Mrs. B., aged 74. The ulcer was situated on the tip of the nose. It measured ½ inch in diameter, and was covered by a thick dry scab. It was coagulated by diathermy on April 8th, 1921. It healed and a healthy scar was left. Two years later a small superficial ulcer was seen at the centre of the scar. It was treated by concentrating ultra-violet rays upon it. It did not heal, and on November 20th, 1923, it measured ¾ inch by ¼ inch. It was then treated by diathermic coagulation and again healed. In March, 1925, ulceration was again seen; in addition there were two small ulcers, one on each cheek. All were treated by diathermic coagulation. In December, 1926, no ulceration was evident. Erythematous scars were present.

In conclusion it may be said that the power of diathermy to kill tissue and infecting organisms without disturbing its anatomical continuity, and to seal lymphatics and blood vessels, should render the new treatment no less successful for lupus than for malignant ulcers. So far the treatment of lupus by diathermy has not been practised as widely as it deserves.

Lupus erythematosus.—Some cases of this intractable disease have been treated by Prof. Bordier, of Lyon, by diathermic coagulation, and good results are claimed. The diseased skin was replaced by scar tissue and no recurrence was noted.

W. J. Harrison, of Newcastle-on-Tyne, treated a case by *medical* diathermy and good results were obtained. The case was in a lady, a private patient of the surgeon named. The disease had affected the skin of the nose and had resisted treatment by methods other than diathermy.

The active electrode was made of sheet lead. A gauze pad, soaked in strong salt solution, was placed over the affected area and covered by the lead electrode. At the first application of diathermy (February, 1921) the current was increased until the heat was the maximum which the patient could tolerate. The duration of the séance was 30 minutes.

Distinct improvement was noted when the patient came for her second treatment in May, 1921. At the second and subsequent applications the current was reduced because a small burn had followed the first treatment. Diathermy was repeated at monthly intervals. In September, 1921, the appearance of the skin was normal. In November, 1921, a small area showed recurrence. This disappeared under further treatment. Applications were made in

November and December, 1921, and in January, February, March and May, 1922. During this period there were no visible signs of the disease, but the patient complained of slight pain and itching towards the end of the month following each application. She remained free from recurrence until January, 1923. During that year she was treated in January, February, March and November. In 1924 and 1925 she was given occasional treatment. In March, 1926, she was again treated. After this treatment she remained free from symptoms until June, 1927, when the premonitory symptoms of pain and itching reappeared. The appearance of the skin, however, was quite normal.

The difficulty in the way of treatment of lupus erythematosus by diathermy is that of measurement of the correct dose. Harrison employed 500 milliamperes at the first treatment; on subsequent occasions 150 to 200 milliamperes were generally used, and on no occasion more than 300. As the writer has insisted, earlier in the present work, the amperemeter is an unreliable guide to dosage. A thermometer in the pad under the electrode or a thermo-couple would give more accurate information.

The writer is indebted to Mr. Harrison for the particulars of the case noted above.

Angiomata.—Fulguration is a rapid and efficient form of treatment of certain forms of nævus. When the constituent vessels are not close to each other, treatment by the galvanic current (electro-chemical cauterisation) is a slow process. Fulguration instantly obliterates the vessels and no permanent mark is left. The sparks can be regulated so as to confine their action precisely to the spot desired. They dry the tissue and do not burn it like the galvano-thermo-cautery.

Fulguration is equally successful for teliangectases, and the cosmetic results are excellent.

In the treatment of capillary nævi fulguration yields better cosmetic results than the galvano-thermo-cautery, but the administration of the anæsthetic which is necessary in children is disturbed. The anæsthetist must not touch the patient while the treatment is given. Carbon dioxide snow is more suitable for this type of nævus.

In the treatment of cavernous angiomata the galvanic

current gives much better results than fulguration or diathermic coagulation. The overlying skin must be sacrificed when the two last mentioned are applied, whereas the galvanic current damages the skin only at the points of entry of the needle and small scars alone are left. Even these can be avoided by covering the needles near their proximal ends by the insulating enamel which is now used in the author's clinic.

In certain cases of cavernous angioma, however, fulguration may give better results than the galvanic current. A medical man visited the Electrical Department of St. Bartholomew's Hospital and said that he had a pulsating nævus on the side of his nose. An attempt had been made abroad to treat it by the galvanic current and the blood spurted from it after the needle had been withdrawn. The nævus measured $\frac{1}{4}$ inch by $\frac{1}{8}$ inch, and it projected about $\frac{1}{8}$ inch above the surface. It was covered by normal skin. Fulguration was administered on three occasions, one-third being treated per séance. The final result of the treatment was a slightly depressed scar which marked the site of the original nævus.

Fulguration was successful, in addition, in the case of a nævus of the left *ala nasi* of an elderly lady. In appearance and size it resembled a red currant and slight pulsation could be felt in it. Free bleeding had occurred at intervals. For this reason it was deemed unsafe to utilise the galvanic current. Fulguration was administered. Two séances of treatment were required to obliterate the nævus.

Fulguration was equally successful in two similar cases. In one of these the nævus was on the bridge of the nose. In the other it was on the right cheek over the malar bone.

In treating cases of this kind the needle electrode used for the fulguration should on no occasion touch the nævus. If this precaution is not taken there will be a likelihood of the adherence of particles of tissue to the point of the needle; when the latter is removed the tissue will come away with it and bleeding will occur.

Papillomata.—Fulguration is an excellent form of treatment for simple papillomata of the skin. The passage of the sparks reduces the tissue to a small hard dry mass.

FIG. 77.—Papilloma of left temple before treatment by fulguration.

FIG. 78.—Same case as that in Fig. 77, three months after fulguration.

Gentle pressure may then dislodge it. The patient shown in Fig. 77 had a papilloma on her temple measuring $\frac{1}{4}$ inch by $\frac{3}{8}$ inch at its base and projecting $\frac{1}{4}$ inch from the surface. It was treated by fulguration. Three months later nothing abnormal was visible (Figs. 77 and 78).

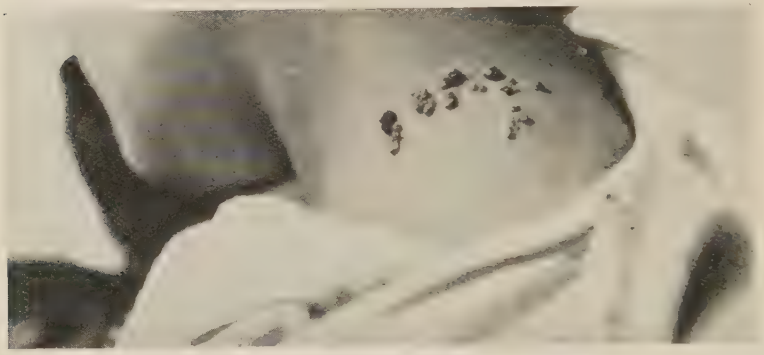


Fig. 79.—Senile warts, before treatment by fulguration.

Fig. 80.—Same case as that shown in Fig. 76, three months after fulguration. (This figure is on a larger scale than Fig. 79.)

Patience and fulguration would probably be successful in the treatment of the multiple papillomata in von Recklinghausen's disease.

Senile Warts.—These, if small, can be destroyed usually by one momentary application of the sparks. Fig. 79 shows a case before treatment.

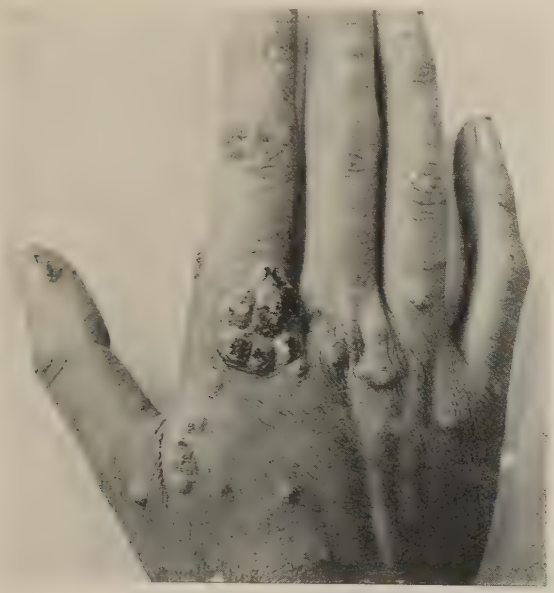


FIG. 81.—Warts before treatment.

FIG. 82.—Same case as that shown in Fig. 81 after fulguration.

The patient was a girl of ten. The warts were on the left side of the neck and varied in size from a currant to a pin's head.

Fig. 80 shows the result. This figure is on a larger scale than the preceding. The arrows indicate the position of the residual scars, which are scarcely visible. No anæsthetic was used for this case.

Warts.—These can be easily destroyed, whatever their size, by fulguration. This treatment is successful for flat warts as well as those which are pedunculated, although the latter can be as effectively removed by the zinc needle and electrolysis. The writer has found fulguration effective in destroying warts which have resisted every other form of treatment, and they have not reappeared.

Fig. 81 shows the warts on the hand of a girl of twenty-two. Fig. 82 shows the result after fulguration by sparks from the diathermy machine and subsequent healing.

Pigmented Areas of Skin.—These may be treated either by fulguration or by superficial diathermic coagulation.

In the former method a local anæsthetic may be given, but most adults can tolerate the operation without it, especially if very short sparks are used in the initial stage. A thin superficial layer is first fulgurated. The sparks are then lengthened slightly and the fulguration repeated so as to dry the tissue to a little greater depth. The process is repeated: sparks as long as $\frac{1}{8}$ inch or $\frac{1}{4}$ inch may be applied. The fulguration must be very thoroughly conducted and each area of tissue must receive the same length of treatment.

The local reaction is slight. The tissue which has been sparked forms a dry adherent scab. Serum collects under the scab and forms a swelling which may cause pain unless it is allowed to escape from time to time by raising the edge of the scab. The latter ultimately separates and a smooth unwrinkled soft scar is left.

The scar must be inspected every three or four months, because specks of pigment may reappear here and there. It is difficult, even after long practice, to remove the pigment from a large area at one sitting. The recurrent spots should be fulgurated again. Repetition of the treatment does not make a hard scar.

Freedom from pigment for six months or a year, or longer, may be obtained by fulguration.

In the author's experience the coagulation of the pigmented skin by diathermy is followed by freedom from reappearance for longer times. For this operation a general anæsthetic is required in cases occurring in children. In adults a local anæsthetic may be given. The pigmented area is moistened and a ball electrode (*e.g.* No. 8, Fig. 54) is moved slowly over it. The current strength and the rate

FIG. 83.—Pigmented mole.

FIG. 84.—Same case as that shown in Fig. 81, after treatment, in part by fulguration, in part by diathermic coagulation.

of movement should be just sufficient to cause a pallor of the pigmented skin.

The coagulated tissue sloughs away and a superficial ulcer is left. The latter must be carefully dressed with lint spread with antiseptic ointment. The scar which is left after healing is smooth and does not contract.

In Fig. 83 is shown a slightly raised hairy pigmented area, dark brown in colour, in a boy of eight. Different portions were treated on different occasions, some by fulguration and others by coagulation. The first operation was conducted in July, 1920. In February, 1921, it was seen that small spots of pigment had reappeared in the scars which formed in the fulgurated areas. These were then coagulated. Fig. 84 shows the appearance in May, 1921.

The scar was pink and there was a slightly raised hard ridge at the lower edge; elsewhere it was soft. This case was shown at the meeting of the Section of Electrology of the Anglo-Franco-Belgian Congress held in London in 1922. The scar was described in the French Report as "assez souple." It was again shown at a meeting of the British Institute of Radiology at St. Bartholomew's Hospital in February, 1926. The scar was soft and there was no pigment.

Fig. 85 illustrates a case of multiple black papillomata in a boy aged $3\frac{1}{2}$. The papillomata were very numerous and closely set together. They were treated by fulguration, the

FIG. 85.—A. MacK., aged $3\frac{1}{2}$. Closely set pigmented black papillomata.

FIG. 86.—Same case as that shown in Fig. 85, twelve months after treatment by fulguration.

patient being under general anæsthesia, on November 24, 1922. On January 19th, 1923, the region formerly occupied by the papillomata showed an erythematous scar containing a few spots of black pigment. These were treated by the same method. In November, 1923, the appearance was that shown in Fig. 86. The scar was free from pigment except in a small spot near the centre. This spot was treated by fulguration. On February 19th, 1926, the scar was pale and soft. A few specks of pigment were seen. (The dark appearance of the scar shown in Fig. 85 was due to erythema.)

Clavus (*Corn*).—Cases of very painful corn sometimes find their way to the practitioner of electro-therapy after unsuccessful trial of various methods of treatment. They can be removed by fulguration, but the treatment must be very

thorough. Half-measures are useless. A local anæsthetic is necessary, and as the insertion of the needle of the syringe is acutely painful, the skin should be first rendered insensitive by spraying it with ethyl chloride. Long thick sparks should be used and the corn thoroughly dried by them. The dried mass may then be excised, but as bleeding is likely to occur the following plan may be adopted. On the next day the foot is soaked in hot water containing a little antiseptic. When the fulgurated tissue is soft it may be detached at the edges. Complete detachment after the first soaking is usually impossible on account of pain which it causes. The process should then be repeated once or twice daily until the destroyed corn has been completely separated.

A severe case was in a lady who was sent to the writer by Dr. Maltby. A horny mass was present on the free end of the little toe. The patient had suffered much pain for two years and was unable to walk far. The toe was very tender to the touch. The corn had been treated by plasters, cutting and "electricity."

Treatment similar to that described above was given. Ten days later the corn had disappeared and the wound had nearly healed.

3. Bladder.

To Edwin Beer, of New York, belongs the credit of suggesting the use of high-frequency currents for destroying intra-vesical neoplasms and of devising a method of performing the operation by way of the urethra. In 1910 he contributed a paper to the *Journal of the American Medical Association* (liv., 1768), entitled "Removal of Neoplasms of the Urinary Bladder." In 1912 he wrote another paper to the same journal (lix., 1784), "Treatment of Papillary Tumours of the Bladder with the High-frequency Current."

Edwin Beer employed the high voltage current from an Oudin resonator attached to a Wappler high-frequency machine. As an active electrode he used a six-ply cable of copper wire, suitably insulated, and cut off squarely at the end which was applied to the growth. He filled the bladder with distilled water. A cystoscope was passed and the free

end of the electrode introduced a short distance in among the villi. The current was passed for fifteen to thirty seconds. Gas was seen to emerge freely from the growth. If the free end of the electrode were placed just in contact with the villi the latter were observed to whiten. Continuation of the current caused the tissue in contact with the electrode to darken and become black, as if it were carbonised.

In 1913 French workers (André, Heitz-Boyer, Legueur, Lepoutre, d'Halluin) employed the high-frequency current from the d'Arsonval machine for the coagulation (electrocoagulation) of growths of the bladder. In the same year German and Austrian operators (Bucky, Casper, Goldberg, Schneider, Stein) contributed papers on the coagulation of bladder growths by the diathermy current.

In the *Clinical Journal* of April 15th, 1914, is a description of a demonstration by Frank Kidd, at the London Hospital, of the treatment of a case of papilloma of the bladder by diathermy. Andrew Fullerton, of Belfast, described the treatment of two cases in the *British Medical Journal* (November 14th, 1914). The two last-mentioned surgeons used a portable high-frequency current generator made by Loewenstein, of Berlin. This apparatus had been demonstrated at the International Medical Congress held in London in 1913.

At the present time diathermy is widely used for the treatment of papillomata of the urinary bladder. The great advantage gained by the use of diathermy is the freedom from recurrence and from the growth of fresh papillomata after the operation. These untoward events are common after use of the scalpel.

For the application of diathermy to the papillomata two electrodes are required. One, the *indifferent* electrode, is placed on some distant part of the body. The other, the *active* electrode, is brought into contact with the growth, either by way of the urethra or through an incision in the hypogastrium and the bladder wall. If the growth is approached by the urethral route a cystoscope and a special active electrode are required. The papillomata are coagulated piecemeal and allowed to slough away. The operation

by way of the urethra is suitable only for small papillomata. It can be performed without a general anæsthetic and the patient need not stay in bed except for a short rest. The operation by way of the hypogastrium is required for large growths. They can be excised by the combined coagulating and cutting operation. A general anæsthetic is necessary and the patient must be confined to bed until the abdominal wound has healed.

(1) *Operation by the Urethral Route.*—The active electrode consists of a narrow springy wire covered, except at its ends, by waterproof insulating material. One end terminates in a short platinum rod with a rounded end. The other extremity is provided with a connection for attachment of the cable from the diathermy machine. This electrode is passed along the side channel of the cystoscope.

The indifferent electrode is a metal plate measuring about 8 inches by 4 inches. It is placed on the patient's abdomen with a pad soaked in strong salt solution intervening between the metal and skin.

If the patient is not given a general anæsthetic the urethra is rendered insensitive with cocaine. An irrigating cystoscope is passed and the bladder washed clear. The active electrode is passed into the side channel of the cystoscope until its platinum tip lies within the bladder. The bladder is now filled with about 12 oz. of sterile water and a papilloma brought into view. The electrode is manipulated until its platinum tip makes contact with the base of the papilloma. If the base is hidden from view by overlying fimbriæ the tip of the electrode is brought into contact with them first. The current is started and gradually increased. The tissue in contact with the electrode is observed to whiten from coagulation. The current is now stopped and the electrode brought into contact with another part of the papilloma. The process is repeated until the overlying fimbriæ have been coagulated.

After a few applications of the current the water in the bladder becomes cloudy and obstructs the view of the operator. The irrigation must then be repeated. Coagulated portions of the papilloma escape with the irrigating fluid. The bladder is then refilled with water and the

current re-applied to the remaining parts of the growth or to other papillomata.

A small area of the mucous membrane around the base of each papilloma is also coagulated.

If it is not possible to treat all the papillomata at one operation, an interval of not less than fourteen days is allowed to elapse before repeating the treatment.

At the end of the operation the bladder must be thoroughly washed out. If any particles of uncoagulated growth remain within the bladder there is a likelihood of the growth of new papillomata.

It is seldom necessary to keep the patient in bed for more than a day or two. For a few days after the operation small sloughs separate and escape with the urine. Occasionally a little bleeding occurs during this time.

A smooth scar is left at the site of the operation.

Considerable experience in the treatment of papillomata of the bladder by diathermy has been acquired by Girling Ball. Those who are interested in the subject should consult a paper contributed by him to the *British Journal of Surgery* for 1924, No. 44. There has been no recurrence of hæmaturia or reappearance of the growths in the cases which were kept under his observation and examined with the cystoscope from time to time. Some of his cases were examined six, seven or eight years after operating.

(2) *Operation by the Supra-pubic Route.*—When the bladder is opened through an incision in the hypogastrium the mucous membrane around the papilloma is covered with wet gauze in order to prevent any separated particles of the growth from falling on the healthy lining of the bladder. The papilloma is grasped below its fimbriæ by suitable forceps. The fimbriæ should not be included in the grip of the forceps for fear of the separation of tumour cells. If the papilloma is pedunculated a right-angle forceps may be used to grasp the pedicle. Slight traction is exercised on the latter so as to pull the mucous membrane of the bladder a little distance away from the muscular coat. A blade electrode is now used to perform the combined coagulating and cutting operation through the healthy mucous membrane around the base of the pedicle. In this way the

papilloma and the healthy tissue for a short distance around the base of the pedicle are removed.

If the growth is sessile the healthy mucous membrane around its base should be grasped by a ring forceps. The papilloma is then drawn a slight distance away from the muscular coat and the mucous membrane coagulated and cut as stated above.

If the growth is sessile and the mucous membrane at its base cannot be grasped by the forceps, the blade electrode is first used to incise the mucous membrane around the base of the growth. The edge on the inner side of the incision is grasped by a forceps and the blade electrode used to coagulate and cut through the healthy mucosa below and around the growth.[1]

Malignant disease of the urinary bladder is unsuitable for treatment by diathermy. Malignant papillomata are difficult to distinguish from benign growths by cystoscopic examination. If the former are treated by diathermy in the same manner as the latter they quickly reappear.

4. Prostate.

G. Luys, of Paris, was the first to employ diathermy in cases of obstruction of the urethra due to enlargement of the prostate. Under the name "forage de la prostate" he communicated to the Société des Chirurgiens, Paris (April, 1918), a method in which the obstructing parts were first seared by the galvano-thermo-cautery: the bleeding surfaces were then coagulated by diathermy.

In this country diathermy has been employed with considerable success by Kenneth Walker (London), J. Everidge (London) and T. E. Hammond (Cardiff). They have obtained the best results in cases in which the obstruction to the outflow of urine was due, not to enlargement of the entire prostate, but to the so-called prostatic bar. This bar can be removed, in part, by a punch operation, *per urethram*,

[1] The coagulation of papillomata by diathermy by the suprapubic route is practised by Herbert Frankling and Claude Saberton, of Harrogate. A full description is given in a book by the latter entitled *Diathermy in Medical and Surgical Practice*, and published by Cassell and Company.

or it can be burnt by a special galvano-thermo-cautery, also *per urethram*. The advantages gained by the use of the diathermy current for the destruction of the bar are the following. The obstruction can be more completely removed than by the punch operation; in the latter the bar cannot be completely cut away. In the operation of diathermic coagulation there is no bleeding, whereas in the cutting and burning operation the hæmorrhage may be profuse.

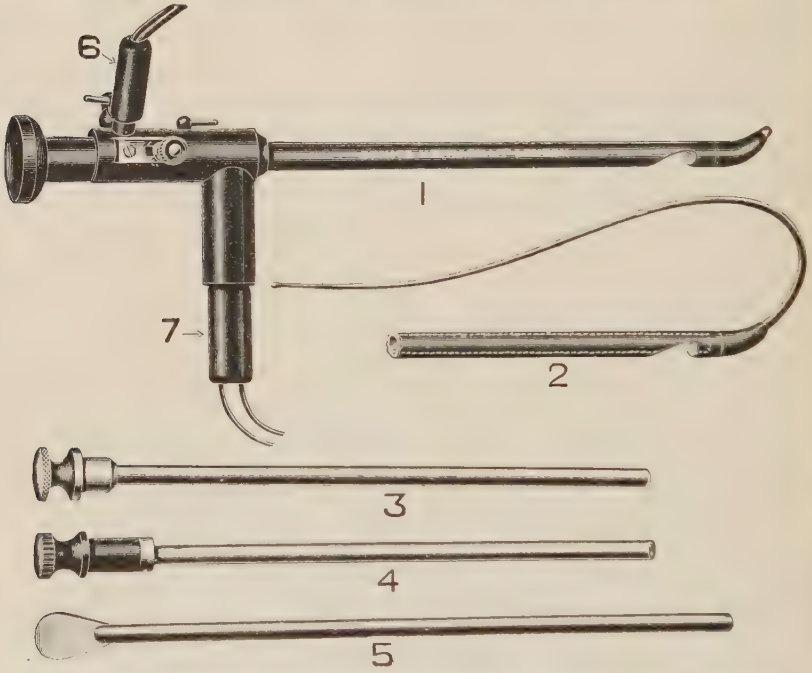


Fig. 87.—The diathermy punch apparatus of Kenneth Walker. (Genito-Urinary Co.)

Kenneth Walker has modified the apparatus, originally devised by Young, for the punch operation, so that it can be used for the application of diathermy. In Fig. 87 are shown the different parts of the modified apparatus. The stem (1), which is introduced into the urethra, is a tube of bakerlite and lined on the inside by metal. The metal does not come in contact with the urethra except at the edge of the window situated below the beak. An obturator

is passed into the stem and the latter is introduced into the urethra. The obturator is then withdrawn, and a system composed of a telescope, a lamp, and inlet and outlet irrigating tubes is inserted. The prostatic bar is made to engage the window of the stem. The diathermy current passes along the metal lining and through the prostatic bar to the indifferent electrode. The coagulation of the bar can be viewed by the operator. The illuminating and irrigating system can then be withdrawn and a tube with sharpened end passed along the stem so as to cut off the coagulated tissue which projects through the window. This gives immediate relief to the obstruction, but further relief is obtained when the coagulated tissue lying outside the window sloughs away.

For a full description of the apparatus and the method of using it the reader should consult the paper contributed by Kenneth Walker to the *British Medical Journal* of January 31st, 1925. In the *Proceedings of the Royal Society of Medicine*, Section of Urology (February 26th, 1925), the same author concludes as follows :

"(1) The diathermy punch has definite advantages over any similar instrument yet evolved. The operation is not a blind proceeding like Bottini's, but is done under full ocular control. It has an advantage over Young's operation in that it eliminates the risk of hæmorrhage, and it allows the easy removal of greater quantities of prostatic tissue, the subsequent sloughing of the diathermy area widening still further the channel dug by the punch. (2) The type of case in which the diathermy punch can be most conveniently employed is that in which there is a 'bar' obstructing the vesical outlet. It may also be used in cases of moderate enlargement in which prostatectomy is contra-indicated, and occasionally in cases of post-operative obstruction and malignant disease."

At a discussion on Surgical Diathermy, held at the Royal Society of Medicine on December 17th, 1926 (see *Proceedings of the Royal Society of Medicine*), J. Everidge stated that he had obtained excellent results by the use of diathermy in certain cases of obstruction caused by the prostate.

In a personal communication, which he has kindly allowed the author to report, Mr. Everidge writes as follows :

"The best cases for treatment are those in which there is either a comparatively small middle lobe projection or a prostatic bar unaccompanied by a palpably enlarged gland. Therefore, cystoscopy

or cysto-urethroscopy are the only means of defining good subjects for diathermy.

"For some years I have been treating such cases in a manner similar to that adopted for diathermic destruction of bladder papillomata, and either have attempted the immediate destruction of the whole projection by means of an electrode introduced through a catheterising cystoscope, or to burrow a hole through a projection in the hope that the overlying gland would slough, leaving a gutter in place of the previous elevation.

"Latterly, the combination of Young's punch and diathermy used in the method described by Walker (*British Medical Journal*, January 31st, 1925) has appealed to me as a more rapid and efficacious measure, and I have adopted it in a considerable number of cases with success.

"Having confirmed the capacity of the patient to withstand interference, a general anæsthetic is given and cystoscopy performed to inspect the field of operation. The punch diathermy cystoscope is then introduced, and under irrigation with saline the projection is treated. Continuous irrigation serves the dual purpose of cooling the fluid in the bladder and washing away blood and debris which might interfere with perfect visibility. The punch attachment is introduced and the projection of the prostate, reduced by diathermy to the physical consistency whereby fragments can be plucked out, is methodically attacked.

"The immediate result may occasionally be to produce a mild degree of irritability of the bladder, and in one or two of my earlier cases sphincter spasm ensued, requiring catheterisation for a day or two. In view of this I make it a rule now to tie in a catheter at the end of the operation, leaving it *in situ* for two or three days. It is not uncommon for a mild basal cystitis, set up by the local irritation of treatment, to last for a week or ten days, accompanied by the passage of fragments and occasionally slight hæmorrhage and pyuria. A liberal supply of fluid by the mouth, washing out of the bladder while the catheter is in place with weak boracic, potassium permanganate or silver nitrate solutions, usually suffice to bring about rapid resolution of the inflammatory effects of the diathermy.

"Cystoscopy after a week will show a gutter, the floor of which is covered by a pale yellow slough, partially separating. At the end of a fortnight any troublesome symptoms will usually have subsided and the urine will have become clear. Inspection then reveals the gutter, bounded laterally by some degree of prostatic elevation, to be covered partly by normal mucous membrane and partly by granulations. Precipitancy and a slight incontinence may be complained of for three weeks, but no case of mine has suffered these symptoms for a long period. Most patients may be allowed up on the third day and are fit to resume their normal occupation at the end of a week.

"Opportunities for employment of this method of treatment are relatively few, for, in both hospital and private practice, I find under 12 per cent. of cases of prostatic obstruction [1] come within its scope, hence statistics of results would, from the paucity of material, be unconvincing. Some of my cases, originally suffering from complete retention of as much as 16 ozs. of residual urine, are now able to empty their bladders completely. Up to the present in not a

[1] Including prostatic carcinoma.

single instance has there been cause for regret either to myself or to the patient that he has been subjected to this method of treatment.

"Fatal cases have been cited, and this is hardly to be wondered at when it is remembered what poor subjects are brought to us for relief. K. Walker (*The Enlarged Prostate*, p. 180) records two deaths in a series of thirty-one patients. Both were cases of complete retention, in one there was severe bladder and renal infection, and in the other marked renal deficiency and infection. Twenty-four cases were cured.

"Naturally, until opportunity has occurred of watching results over a period of years, it would not be wise to make too dogmatic statements, but in the light of present knowledge, gained from a fair experience, I am encouraged to believe that diathermic destruction of certain cases of intravesical prostatic projections is a definite addition to the armamentarium of the urological surgeon."

T. E. Hammond (*British Medical Journal*, January 16th, 1926) recommends diathermy for the large and small fibrous prostates and the atrophied prostate where the urethra is obstructed at the neck of the bladder. "After treatment by diathermy," he states, "shock and hæmorrhage are never severe enough to cause any worry, the convalescence is much shorter than after prostatectomy, the functional result is better, and the mortality is less. In twenty cases done so far by me there has been one death. When it is remembered that the type of prostate which is treated by diathermy is that which is largely responsible for the mortality after prostatectomy, it is obvious that a careful selection of cases will lead to an improvement in the statistics of this operation."

5. Rectum and Anus.

Hæmorrhoids.—Various electro-thermic methods can be used for the destruction and removal of hæmorrhoids, and different methods of performing the operation have been described. Little has been written on the subject by English workers, but in the United States the new methods have been described in various books and periodicals on physiotherapy, and seem to be more widely used than in Europe. In the absence of any standardisation of methods a brief description of the procedure of some operators will be given.

Dr. Turrell,[1] of Oxford, paints the protruded piles with

[1] *The Principles of Electrotherapy and their Practical Application*, Oxford Medical Publications.

5 per cent. solution of novocaine or injects 1 per cent. solution of the same substance around the anus. The piles are then coagulated by diathermy. The current is gradually increased until the pile under treatment acquires an ashen-grey appearance or actually bursts by expansion of the heated gases in its interior. The current should not exceed 300 ma.

A considerable amount of swelling of the surrounding tissues and some pain usually follow the operation, and Dr. Turrell advises that the patient should be kept quiet, but not necessarily in bed, for ten days.

Prof. Bordier,[1] of Lyons, recommends a light general anæsthetic. He coagulates the external or prolapsed internal piles by the diathermy current. He states that the patients suffer some pain when the coagulated parts are sloughing away and that it is occasionally necessary to apply morphine suppositories.

Dr. W. L. Clark, of Philadelphia, originally practised his method of electro-desiccation for the treatment of hæmorrhoids. In a recent contribution to the *American Journal of Electrotherapeutics and Radiology*[2] he has described the following methods.

In the case of external hæmorrhoids a local anæsthetic is given and a line of desiccation is drawn across each pile, instead of a primary incision with a scalpel. The needle electrode is then inserted into the clot, which is desiccated and the vein destroyed. The hæmorrhoid is then incised through the desiccated line without hæmorrhage and the desiccated clot curetted out. Relief is immediate and healing is rapid.

In the case of internal piles the sphincter is infiltrated with a 2 per cent. solution of novocaine containing a little adrenalin. Two to three cubic centimetres are injected. The anus is now dilated and each pile in turn is drawn down by tenaculum forceps and desiccated. Each pile is grasped at its base by a clamp and desiccated down to its base. The clamp may then be removed. Hæmorrhage does not occur.

Dr. Clark says that the post-operative discomfort is so

[1] *Diathermie et Diathermothérapie*, Baillière & Fils, Paris.
[2] Vol. XLIII, No. 9, September, 1925.

slight that patients can proceed with their duties of life immediately after the operation, but that this is not advisable if the case is a bad one. A rest in bed for a few days should then be ordered.

Fulguration is employed by some workers. By the courtesy of Dr. Bierman the author was able to see the performance of this operation on one of his private patients in New York. The patient was placed in the lithotomy position and the anal sphincter was infiltrated with novocaine and adrenalin. The anus was then dilated and the hæmorrhoids brought into view. Sparks of 1 inch or 1½ inches were directed on each pile in turn. The active electrode was connected to an Oudin resonator, the patient being earthed. The piles gradually shrunk in size and were converted into small dried masses of tissue.

Recently Dr. Bierman [1] has devised a special clamp for grasping hæmorrhoids at their base and the passage of the diathermy current between the jaws of the clamp. In this way the piles can be sealed at the base and removed.

Of the different methods the best appear to be those in which the hæmorrhoids are sealed at the base by diathermy and then removed. They resemble the clamp and cautery method, but the sealing is more effective and there is little cicatricial contraction after healing. Those who have had experience say that a soft non-contracting scar is left after desiccation. Dr. Wyeth [2] states that the treatment of hæmorrhoids by desiccation "cannot be too highly commended to the surgeon who has long wished for an operation for the removal of hæmorrhoids which is quick and clean, unaccompanied by hæmorrhage or shock, and which leaves the tissues soft and pliable."

If internal or prolapsed hæmorrhoids are coagulated and allowed to slough spontaneously there is always the likelihood of pain and swelling for a few days after the operation.

The writer's experience in the treatment of hæmorrhoids by surgical diathermy is limited to a few cases. In some of these the hæmorrhoids were permanently prolapsed and

[1] *Physical Therapeutics*, Vol. XLV, No. 1, January, 1927.

[2] *Treatment of Neoplastic Diseases by Electrothermic Methods*, p. 199, Paul B. Hoeber; New York.

contained much fibrous tissue. They were coagulated by diathermy under local anæsthesia, and the patients suffered little or no discomfort after the operation. In two cases in which the hæmorrhoids had been of less long duration there was considerable pain for a few days after the operation. Both patients, however, had suffered considerably *before* the treatment. The final result was complete relief. In another case there were three permanently prolapsed piles but no pain. Each was treated by a special bi-polar needle electrode. The two needles were mounted on a holder and connected to the two terminals of the diathermy machine. The needles were inserted into one of the piles and the current increased to the limit of toleration. The patient suffered no further discomfort. Three weeks later the pile had disappeared. The second and third were treated in the same way with the same results.

Anal Fissure.—In most cases the pain can be abolished and the fissure healed by *medical* diathermy (see p. 205). The heat abolishes the painful spasm of the sphincter and aids the healing of the fissure. In some cases it may be necessary to apply additional treatment to the latter. Ionisation by zinc disinfects the fissure and covers it with a sterile protective layer of zinc albuminate which remains in position for a week or longer. Healing proceeds from below. One application is usually sufficient.

Papillomata of the Rectum and Colon.—The case described below is an example of the usefulness of diathermy in the treatment of multiple papillomata of the rectum and colon. This case was treated by Mr. Andrew Fullerton, surgeon to the Royal Victoria Hospital, Belfast, who kindly described the details to the writer and gave permission for their publication.

The patient, a woman of 28, had suffered for two or three years from occasional pain in the abdomen and irregular action of the bowels. At times she had passed blood by the bowel, sometimes mixed with matter. On examination with the sigmoidoscope a small papilloma, about the size of a split-pea, was seen in the rectum, about two to three inches up. It was shaved off. Two or three more papillomata, about the same size, were seen between the first one and a point 10 cm. higher up. The removed papilloma was examined. The section showed that it was simple and resembled an adenoma.

On May 11th, 1925, five papillomata were destroyed by diathermy through the sigmoidoscope. The highest was about 15 cm. from the anus.

On June 26th, 1925, the sigmoidoscope revealed no papillomata. The bowels were loose and occasionally a little blood was passed.

On October 21st, 1925, a papilloma about the size of a pea, and with a short pedicle, was seen about 17 cm. up. It was destroyed by diathermy.

On February 13th, 1926, no papillomata were seen. The diarrhœa was less.

On May 15th, 1926, a papilloma, about the size of a marble, was seen about 20 cm. up. It was destroyed by diathermy.

On July 2nd, 1926, the treatment was repeated. The patient complained later of cramp-like pains in the abdomen, and the stools continued to be loose.

On August 9th, 1926, laparotomy was performed. A large fleshy mass was felt in the pelvic colon. The bowel above this was somewhat dilated. Other smaller round soft masses could be felt as far back as the cæcum. The large intestine and about four inches of the small intestine were removed. A lateral anastomosis was made between the ileum and rectum.

On slitting up the portion of bowel removed there were found a large number of sessile polypi varying in size from that of a hemp seed to that of a marble. One large conglomerate mass was found in the pelvic colon measuring $3\frac{1}{2}$ inches by $2\frac{1}{2}$ inches. These papillomata were pink in colour and closely resembled those commonly found in the bladder. A portion of the large tumour was examined by Prof. Symmers and pronounced to be papillomatous adenoma.

The patient went home on September 28th, 1926, feeling very well and passing semi-solid motions twice a day.

On January 26th, 1927, the sigmoidoscope was passed. The rectum was free from papillomata. The patient was last heard of in March, 1927 (a few days before the case was described). Though not strong she was able to get about and was comfortable.

Commenting on this case Mr. Fullerton stated that the treatment of the rectal papillomata by diathermy enabled him to preserve the rectum up to the point of anastomosis—a very important fact from every point of view.

The use of Diathermy in Surgical Shock.

Diathermy has been used by George Crile, of Cleveland, Ohio, both for the prevention of shock during operation and for its treatment after operation. For the first purpose the liver is subjected to diathermy during the performance of the operation, the object desired being the warming of the blood after its temperature has been lowered in its passage through the exposed abdominal viscera.

For the second purpose general diathermy is administered,

one electrode being applied to the head, and two others to the feet.

The reference to the use of diathermy by Crile for shock can be found in *Surgery, Gynæcology and Obstetrics*, February, 1926, p. 218.

Prof. A. W. Sheen, of Cardiff, has used diathermy, with apparent benefit, during two abdominal operations. It was applied to the liver in order to warm the portal blood.

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